Modeling Evaluation Study for the Union Pacific J.R. Davis (Roseville) Rail Yard

prepared for:

Placer County Air Pollution Control District

September 2011

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1. EXECUTIVE SUMMARY

This document is a report on an evaluation of air dispersion modeling results compared to pollutant concentrations measured during the Roseville Railyard Air Monitoring Project (RRAMP). This modeling evaluation project is funded by the Placer County Air Pollution Control District (PCAPCD) and Union pacific Railroad (UPRR) as a follow-up study of the original RRAMP. The two objectives of this comparison study were (1) to perform sensitivity analyses to determine how modeled ground-level concentrations of Diesel particulate matter (DPM) and NOx[1] differ between the use of two different models (AERMOD[2] and ISCST3[3]), use of two different dispersion modes (rural and urban), and use of two different sets of hourly meteorological data; and (2) to compare modeled DPM and NOx concentrations for the rail yard to DPM-surrogate[4] and NOx concentrations measured at ambient monitoring stations located near the rail yard as part of the RRAMP study.

The RRAMP was a four-year air monitoring study of the air pollutant concentrations near the UPRR J.R. Davis (Roseville) Rail Yard facility. Compared to many other large rail yards located in urban areas, the Roseville Rail Yard is relatively unique. No freeways, other major roadways, or large truck distribution centers are located near the rail yard, which reduces the opportunity for emissions from rail yard activities to be assigned impacts in the monitoring data that are actually caused by sources outside of the rail yard. In addition, the Roseville location has stable nighttime meteorology in which the prevailing wind blows roughly perpendicular to the narrow dimension of the rail yard between mid-June and mid-October. These factors not only facilitate an air monitoring study to determine whether air pollutant concentrations related to the emissions at the

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[1] Rail yard emissions input into the dispersion models were NOx emissions (total of NO and NO_2), calculated as NO_2. Although dispersion model outputs were also calculated as NO_2 assuming 100% conversion of NO to NO_2, the short distances and travel times from the rail yard sources to the downwind monitors in the study allowed little conversion of NO to NO_2. The ambient monitors detected and reported NO and NO_2 separately. To facilitate comparisons, all references to NOx and NOx (as NO) ambient concentrations in this report, whether measured or modeled, refer to NOx calculated as NO.
[2] AERMOD stands for American Meteorological Society/Environmental Protection Agency Regulatory Model, and was developed by the American Meteorological Society/Environmental Protection Agency Regulatory Model Improvement Committee.
[3] Industrial Source Complex Short-Term, Version 3. This model was used because it had been used in the earlier modeling study conducted by the ARB (ARB, 2004).
[4] The DPM-surrogates measured in the RRAMP monitoring program (Campbell and Fujita, 2006, 2007, 2008, and 2009) included black carbon, elemental carbon plus organic carbon, and $PM_{2.5}$.

Roseville Rail Yard can be identified, but also provide a unique opportunity to perform a comparison of air monitoring and computer modeling results.

Measurements of ambient concentrations from the RRAMP included nitric oxide (NO), nitrogen oxides (NOx), $PM_{2.5}$,[5] and black carbon[6] (BC), which were taken over a four-year period (2005-2008) at four monitoring stations sited in two upwind/downwind pairs around the northeastern end of the Roseville railyard. In the first-year (2005), one pair of monitoring stations began operating from mid-July to mid-October and another pair was operated from early-September to mid-October, which resulted in a shorter monitoring period in the first year (2005) compared to the following years (2006-2008).[7] From 2006 to 2008, measurements were made at all four stations late at night (10 PM to 5 AM PST) from mid-June through mid-October. The nighttime periods, during which winds blew predominantly across the rail yard, minimized the intrusion of non-rail-yard source emissions between the upwind/downwind monitor pairs. Periods of time when the wind was not blowing from the direction of the ―upwind" monitors were excluded from the RRAMP analysis. The resulting pairs of measurements were used to determine rail yard impacts by subtracting upwind concentrations from downwind concentrations.

In the comparison of monitoring data and modeling results, seasonal[8] average concentration differences measured in the RRAMP study are compared with concentrations of NOx (as NO) and DPM predicted by dispersion models. Both the AERMOD and ISCST3 dispersion models were run using both rural and urban dispersion coefficients. Table 1 and Table 2 summarize this comparison and will be discussed in more detail later.

In addition to the above comparison, sensitivity analyses of the dispersion model results were performed using (1) meteorological data from two meteorological towers, one onsite and the other at the nearby ARB Roseville meteorological and air quality monitoring station; (2) annual average or ―seasonal" data from all four RRAMP years; and (3) all four model/mode configurations. Differences between the resulting modeled concentrations using the two meteorological sets were minor. All four model/mode configurations predicted significant reductions in both DPM and NOx impacts over the four-year period, due to reductions of emissions and relocation of sources at the rail yard over that period. Significant reductions in measured concentration differences were also observed over that period, as previously reported for the RRAMP study (Campbell and Fujita, 2009). However, the agreement between modeled and monitored results was more qualitative (directional) than quantitative (magnitude).

The four model/mode configurations predicted concentrations within a factor of two of each other; thus, while the relative performance of the configurations was good from the perspective of evaluating trends directionally, the absolute concentrations predicted by the configurations, and the magnitudes of the predicted reductions over time, were not

[5] Particulate matter with aerodynamic diameter less than or equal to a nominal 2.5 micrometers.
[6] Other compounds measured included elemental carbon and organic carbon.
[7] See Section 4.1 ―RRAMP Data" for more details on the monitoring program.
[8] ―Seasonal" refers to the RRAMP monitoring season, which ran from mid-June through mid-October. No four-season (spring, summer, fall, winter) monitoring was conducted in the RRAMP study

close to measured concentrations. In the inter-comparison of the four model/modes, higher DPM and NOx annual average concentrations were predicted using rural coefficients as compared with urban coefficients. For the limited conditions of the RRAMP monitoring season (wind always from the same direction), ISCST3 predicted higher impacts using urban coefficients as compared with rural coefficients, while AERMOD predicted slightly higher impacts with rural coefficients. These comparisons are presented in Section 5.1 of the report.

Table 1 – Comparison of ambient measurements with model predictions (RRAMP Season average nighttime NOx (as NO) concentrations; modeling based on onsite meteorological data)

	Basis	2005	2006	2007	2008
Denio site, RRAMP season average nighttime concentration	Measured[a] ($\mu g/m^3$)	167	123	94	34
	Modeled[b] ($\mu g/m^3$)	63	63	52	39
	Modeled/Measured Ratio	0.38	0.51	0.55	1.15
Church site, RRAMP season average nighttime concentration	Measurement[a] ($\mu g/m^3$)	146	116	123	43
	Modeled[b] ($\mu g/m^3$)	37	32	30	23
	Modeled/Measured Ratio	0.25	0.28	0.24	0.53

[a] Measured value calculated by subtracting upwind monitor value from downwind value to get net facility impact.

[b] Average of AERMOD (rural), AERMOD (urban), ISCST3 (rural) and ISCST3 (urban) predicted concentrations.

Table 2 – Comparison of ambient measurements of Black Carbon and $PM_{2.5}$ with model predictions of DPM (RRAMP Season average nighttime concentrations; modeling based on onsite meteorological data)

	Basis	2005	2006	2007	2008
Denio site, RRAMP season average nighttime concentration	Measured (Black Carbon)[a] ($\mu g/m^3$)	2.05	2.68	1.61	0.72
	Measured ($PM_{2.5}$)[a] ($\mu g/m^3$)	9.00	4.80	3.00	2.50
	Modeled[b] ($\mu g/m^3$)	2.91	2.80	2.25	1.70
	Modeled DPM/Meas. BC	1.42	1.04	1.40	2.36
	Modeled DPM/Meas. $PM_{2.5}$	0.32	0.58	0.85	0.68
Church site, RRAMP season average nighttime concentration	Measured (Black Carbon)[a] ($\mu g/m^3$)	1.74	1.79	2.40	1.12
	Measured ($PM_{2.5}$)[a] ($\mu g/m^3$)	10.70	6.30	6.90	2.40
	Modeled[b] ($\mu g/m^3$)	1.70	1.37	1.27	0.96
	Modeled DPM/Meas. BC	0.98	0.76	0.53	0.86
	Modeled DPM/Meas. $PM_{2.5}$	0.16	0.22	0.18	0.47

[a] Measured value calculated by subtracting upwind monitor value from downwind value to get net facility impact.

[b] Average of AERMOD (rural), AERMOD (urban), ISCST3 (rural) and ISCST3 (urban) predicted concentrations.

Table 1 and Table 2 show, for NOx (as NO) and DPM, respectively, the differences between the measured concentrations from the RRAMP study and the predicted concentrations from the models. The dispersion models systematically either underpredicted (by up to a factor of six) or overpredicted (by up to a factor of two) concentrations of different pollutants at the precise locations of the four RRAMP monitoring stations and under the conditions of this analysis. Some possible explanations for these differences are listed below.

- Limitations in modeling and monitoring: Air dispersion modeling and air monitoring are two different approaches to serve the different purposes for the air pollution study. In general, air dispersion models work well to predict changes in ambient concentrations at different locations over different periods of time having different emissions from known sources. In contrast, air monitoring focuses on the measured concentrations at a fixed location to present the impacts from actual emissions, without requiring knowledge of source strength or location. Therefore, dispersion modeling is more suitable to predict the magnitude of concentrations, with some uncertainty as to the precise location of the impacts, while ambient monitoring is more suitable for determining ambient concentrations at precise locations without determining source locations or strengths. Thus, one reason for the observed differences is the inherent limitation in the two analytical techniques.

- Impacts from nearby or unexpected sources: It is possible that the measurements from the RRAMP study were impacted by nearby or unexpected sources, which were either unaccounted for or inadequately accounted for in the modeling. Although the RRAMP study design was intended to eliminate, or minimize, interference from other sources, it is possible that this objective was not consistently met each year.

- Imprecise characterization of emission sources: The predicted concentrations from models are based on the known source characterization, including the location, strength, and dispersion characteristics of each emission source. In this analysis, the modeled concentrations exhibit a high degree of spatial variability in concentrations in the vicinity of the two downwind monitors. Receptors separated by 50 meters show as much as a 70% difference in predicted concentrations. The highest predicted concentration within 100 meters of the Church monitor site is more than 3.8 times the prediction at the monitor location. These findings indicate that a small mischaracterization in location or strength of one or more sources could significantly affect the predicted concentration at the observed location. This is a likely contributor to the observed difference between results.

As shown in Table 1, and discussed in more detail in Section 5.3 below, a comparison of measured NOx (as NO) concentrations with modeled concentrations did not show good agreement. The data show that the model systemically underpredicted NOx (as NO) concentrations from the railyard. For a given year, the average of the four model/mode predictions of RRAMP season average nighttime NOx (as NO) concentrations was low by a factor of up to 4.

As shown in Table 2, and also discussed in more detail in Section 5.3 below, comparisons of the measured $PM_{2.5}$ concentrations with the DPM concentrations predicted by the models also do not show good agreement. However, the ratios of measured $PM_{2.5}$ to DPM predictions are similar to those of measured and predicted NOx. This would suggest that any adjustments to the models that improve their ability to predict NOx concentrations may improve the agreement between $PM_{2.5}$ measurements and DPM predictions.

BC has frequently been used as a surrogate for DPM because DPM was not, and cannot be, directly measured in the atmosphere. Comparison of the measured BC concentrations with the DPM concentrations predicted by the models showed fair agreement for some years/sites, and poor correlation for others. As discussed above, there is an observable discrepancy between the measured NOx (as NO) and $PM_{2.5}$ concentrations and the predicted NOx (as NO) and DPM concentrations. NO is a specific chemical compound that is essentially non-reactive under the short transport distances and nighttime conditions evaluated in this study. Consequently, it is logical to expect that the uncertainty in the model-predicted dispersion of NOx from the facility would also characterize the uncertainty in the model's prediction of dispersion of any other pollutant. A detailed comparison of hourly predictions with hourly measurements, which is beyond the scope of this analysis, might help understand the cause of this fundamental discrepancy. The reason for the apparent agreement found in this study between measured BC and modeled DPM concentrations during some years at some locations, when the NOx correlation is poor, may require further investigation.

Finally, the RRAMP monitors were located close to the rail yard to reduce interference from other sources. However, they appear to have been located so close to the rail yard that a small change in source location or strength could significantly change the measured concentrations. We believe that this trade-off – the need to reduce interference from other sources, as compared with modeling and monitoring uncertainty introduced due to short source-receptor transport distances – is a major factor that contributes to the observable difference between the model predictions and monitoring measurements; this is an important factor which needs to be evaluated in any future similar studies.

2. INTRODUCTION

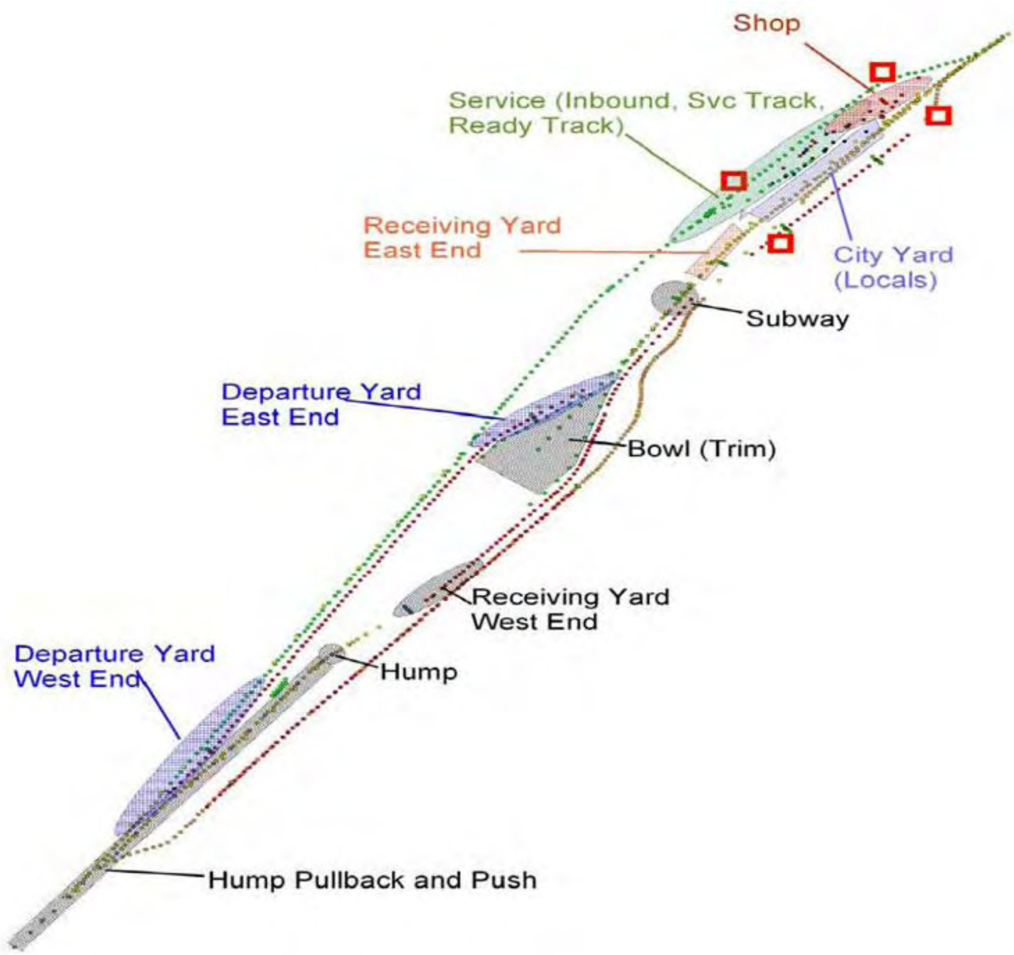
The two purposes of this study are to (1) perform sensitivity analyses to determine how modeled ground-level concentrations of DPM and NOx differ between the use of two different models (AERMOD and ISCST3), use of two different dispersion modes (rural and urban), and use of two different sets of hourly meteorological data (one obtained at a monitoring station located at the rail yard and the other located at the nearby offsite California Air Resources Board (ARB) monitoring station in Roseville; and (2) compare modeled DPM and NOx concentrations for the Union Pacific Railroad (UPRR) J.R. Davis (Roseville) Rail Yard to DPM-surrogate and NOx concentrations[9] measured at ambient monitoring stations located near the rail yard as part of the Roseville Rail Yard Air Monitoring Program (RRAMP). This modeling evaluation may provide useful information regarding the interpretation of the monitoring data collected in the RRAMP study despite the fact that the selected models were designed to simulate dispersion over scales of kilometers to tens of kilometers while the cross rail yard dimension is only on the scale of hundreds of meters.

[9] NO and NOx ambient concentrations were measured by chemiluminescence instruments.

3. BACKGROUND

The J. R. Davis Rail Yard is located in Roseville, California and encompasses about 950 acres on a one-quarter mile wide by four-mile long strip of land that parallels Interstate 80. The western end of the Yard is located in Sacramento County and the remainder of the Yard is in Placer County. The Yard is bounded by commercial, industrial, and residential properties. The Yard is the largest of UPRR's service and maintenance rail yard in the West, with over 30,000 locomotives visiting annually. A schematic of the Yard is shown in Figure 1.

Figure 1 – Schematic of Roseville Rail Yard



Under an agreement with the Placer County Air Pollution Control District (District or PCAPCD), and with support from UPRR, the ARB conducted a study of locomotive emissions, including air dispersion modeling, for the Roseville Yard between 2000 and 2004. The results of this modeling were used by ARB to estimate population exposure and health risks associated with rail yard-related emissions.

Based on the findings in ARB's 2004 Report, the District, with support from UPRR, initiated the RRAMP in 2005. As stated in the RRAMP Air Monitoring Plan (Placer County APCD, 2005), the objectives of the RRAMP study were to:

1. To determine, through ambient air monitoring, localized air pollutant impacts from the emissions at the UPRR facility;
2. To verify the effectiveness of mitigation measures (over time) by UPRR;
3. To improve the accuracy of future modeling analyses;
4. To provide feedback to the public regarding air quality conditions relevant to objectives (1) and (2).

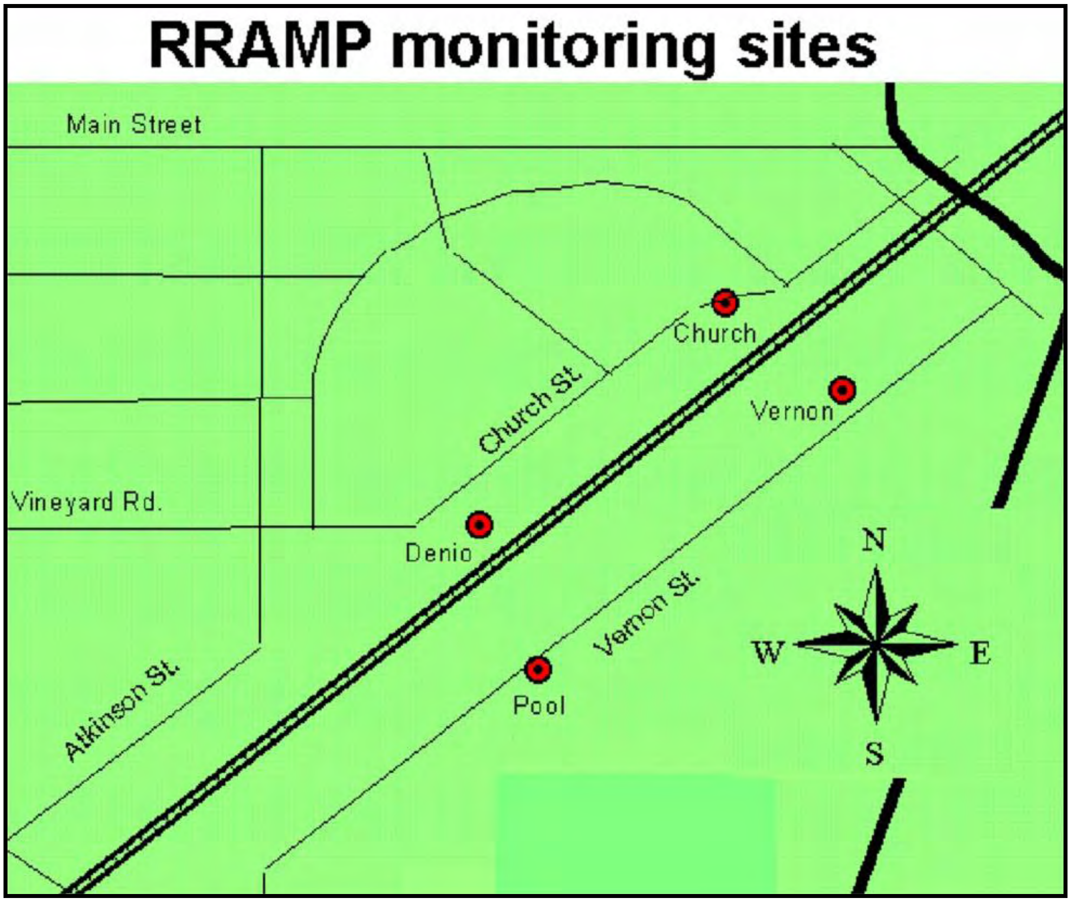
The RRAMP study was originally intended to be a three year study from 2005 through 2007, with monitoring conducted from mid-June to mid-October of each year. The program was extended by one year to collect data during the same period in 2008.

As discussed above, one of the main objectives of the RRAMP study was to determine the contribution of UPRR facility emissions to local air quality, and to determine if benefits from emissions mitigation efforts implemented by UPRR over the study period of RRAMP could be detected. The prevailing wind directions during the late night through early morning hours in summer and early fall provided conditions that were most favorable for achieving the monitoring objectives for the study.

Monitoring for the RRAMP was conducted at two upwind/downwind pairs of monitoring sites aligned as optimally as possible to the prevailing late nighttime wind direction that most persistently is from the southeast, and aligned approximately perpendicular to the rail yard tracks. The map in Figure 2 shows the locations of the two upwind (Pool and Vernon) and two downwind (Denio and Church) sampling sites. The close placement of the monitors to the rail yard helped to reduce potential interference by other emissions from sources throughout the surrounding city, but made it difficult for each monitor to respond to emissions from all the activities occurring within the 4-mile long rail yard. Meteorological data were collected at an onsite monitoring tower, and at the Roseville ARB monitoring station, which is located at 151 N Sunrise Blvd, approximately 1.5 miles east of the rail yard shown in Figure 2. In addition, wind speed and wind direction data were also collected at the four RRAMP monitoring stations. The RRAMP data analysis reports for each monitoring year are available from the PCAPCD website.[10]

[10] http://www.placer.ca.gov/Departments/Air/railroad.aspx.

Figure 2 – Map showing locations of the two upwind (Pool and Vernon) and two downwind (Denio and Church) sampling locations surrounding the UP J.R. Davis Roseville Rail Yard.



Note: The upwind directions from the Church-to-Vernon and Denio-to-Pool station pairs are 132 and 177 degrees, respectively.

The conclusions contained in the final RRAMP study report are outlined below.

- Since concentrations at the upwind sites are near zero for NO, essentially the entire concentration of NO observed at the downwind sites is attributable to emissions from the rail yard.[11] (Christofk, 2009)

- The relative magnitude of pollutant measurements at upwind and downwind sites, and the relatively high ratio of NO to NO_2 at the downwind sites were strong indicators the upwind sites truly were upwind, and downwind sites truly were downwind, of the facility. As a result, the difference between downwind and upwind measurements was a good indicator of the impacts from facility emissions at the downwind monitoring site.[12]

[11] Christofk (2009), p. 6.
[12] Christofk (2009), p. 12

- A steadily decreasing trend in NO and NOx is seen at Denio and a similar, but less consistent, decrease at Church for the 3 years of complete data from that site. The overall decrease in NO net concentration difference from 2005 to 2008 is 80% at Denio and only slightly less (72%) at Church for 2006 to 2008.[13]

- BC concentrations were variable and had no clear trend at the downwind monitoring sites, although there was a large decrease from 2007 to 2008. Upwind BC concentrations were very low. The calculated net differences between downwind and upwind measurements showed good agreement between patterns of concentrations at the two downwind sites.[14]

- Upwind $PM_{2.5}$ concentrations were higher and more variable than other pollutant concentrations because they include a substantial regional background component, which is typically composed of inorganic compounds (ammonium nitrate, sulfate, and mineral oxides).[15]

- Nearly equal $PM_{2.5}$ concentrations were observed at the two downwind sites.[16]

- A decreasing trend in $PM_{2.5}$ concentrations (60-75% reduction over the four year period of the RRAMP study) was observed at both downwind sites.[17]

- The progression in RRAMP period means net differences (upwind minus downwind) from year to year are consistent for all pollutants, with a small decrease from 2006 to 2007 and a much larger drop from 2007 to 2008.[18]

- In comparing emission reductions with changes to downwind concentrations, the overall pattern is similar (small reduction from 2006 to 2007, larger drop from 2007 to 2008). However, the reduction in downwind concentrations was much greater than the reduction in emissions. One possible explanation for this was that activities in close proximity to downwind monitors, such as load testing, became more widely distributed spatially during the 4-year study. Moving emissions away from the monitor, or spreading them out over the facility, would tend to decrease the measured impact without a reduction in emissions.[19]

- The available activity and emissions data are daily records and not sufficiently spatially detailed to narrow down to the 7-hour nighttime monitoring period.[20] The nighttime period provided a relatively stable wind direction across the rail yard from the southeast towards the northwest, which is why it was selected for the RRAMP study.

[13] Christofk (2009), p. 6
[14] Christofk (2009), p. 7
[15] Christofk (2009), p. 8
[16] Christofk (2009), p. 8
[17] Christofk (2009), p. 8
[18] Christofk (2009), p. 8
[19] Christofk (2009), p. 10
[20] Christofk (2009), p, 11

4. METHODOLOGY

This section summarizes the methodologies used to prepare the various data sets and project components for use in this study. Each component is discussed in detail below.

It should be noted that there were two distinct activities performed for this project: an analysis of the sensitivity and variability of modeling results with regard to choice of model, choice of source of meteorological data, and changes in emissions over the RRAMP study period; and a comparison of measurements with the predictions from modeling. Comparisons between measurements and modeling results used limited data (i.e., RRAMP season data, from the portion of the year when prevailing winds facilitated analysis, restricted to a portion of the day when winds tended to be steady in direction and speed). The sensitivity analyses, on the other hand, used annual emission data and the full year of meteorological data.

4.1 RRAMP Data

Pollutant concentration data were collected for four consecutive RRAMP seasons (mid-June to mid-October)[21] at the two upwind/downwind pairs of monitoring sites. Three screening criteria were established to determine the conditions upon which upwind-downwind analyses are appropriate: (1) winds need to be from a semi-circular arc between 45 degrees (i.e., northeasterly) through 225 degrees (i.e., southwesterly); (2) only winds from 0.5 to 4 m/s were used to avoid calm or windy conditions; and (3) only 7 overnight hours from 10 PM to 5 AM PST were used. This is the time frame when the winds blow most consistently across the rail yard directly from the upwind to the downwind locations, and therefore the rail yard emissions can most readily be detected.

The quality-assured data for the pollutants listed below were assembled for each June-October monitoring period.[22]

- Black carbon (BC) (by aethalometer)
- $PM_{2.5}$ (by beta attenuation monitor [BAM], which provided hourly concentrations for 2006-2008. This ―ifial" method replaced the next method.)

[21] The 2005 monitoring period was shorter by one month at the Denio site (i.e., operated from mid-July to mid-October), and shorter by three months at the Church site (i.e., operated from mid-September to mid-October). This final month had wind directions more from the north, during which the ambient concentration monitoring data could not be used in this study.
[22] Campbell and Fujita (2009)

- $PM_{2.5}$ (by 24-hour integrated gravimetric federal reference method every 9th day during entire 2005, and part of 2006, RRAMP seasons only. This ―initial" method did not provide sufficient temporal resolution; it was replaced by the BAM method.)
- Nitric oxide and Nitrogen Oxides (NO and NOx) (by chemiluminescence)

Air Dispersion Models – An air dispersion model is a mathematical approximation of atmospheric processes, which is used to predict concentrations at a specified location, known as a receptor, based on site-specific emissions data and meteorological inputs. The model used in ARB's Roseville Study, ISCST3, was designed as a regulatory model to be used to demonstrate the impact of emission controls in efforts to achieve air quality standards, and to determine if a proposed facility complies with Prevention of Significant Deterioration (PSD) allowable ambient air quality increments. As such, its developers at the U.S. Environmental Protection Agency (EPA) sought a model that would not underestimate concentrations for averaging time periods of regulatory interest (i.e., 1 hour to 1 year). However, a computer model is by necessity a simplification of reality. Not everything that can affect the resulting ambient concentration can be included in the model—simplifying assumptions must be made. Furthermore, a model's accuracy is also limited by the availability and quality of input data. Although designed for regulatory purposes to overestimate concentrations, under some conditions ISCST3 underestimates concentrations.

ISCST3 has now been replaced by the AERMOD modeling system as EPA's preferred model. The AERMOD system includes enhancements in the preprocessing of meteorological, land-use, and terrain data for characterizing dispersion, as well as in the dispersion calculations related to plume rise, downwash, and turbulent diffusion.

ISCST3 and AERMOD are both steady-state multiple-source models designed for use with emission sources situated in terrain where ground elevations can exceed the release heights of the emission sources (i.e., complex terrain). Both models also have the ability to simulate air dispersion in rural environments, where the type of vegetation cover determines the surface roughness and influences the resulting turbulence, and to simulate dispersion in urban environments, where buildings and other manmade structures determine surface roughness and influence the resulting turbulence. The two modes of the ISCST3 model are called ISC Rural and ISC Urban. AERMOD approaches the different dispersion in the two land use settings by having an ―URBAN OPTION" that is turned off or on to simulate a rural or urban atmosphere, respectively.

EPA makes available studies (USEPA 2003a, 2003b) of the performance of AERMOD relative to its predecessor ISCST3, both of which were used in this study. The comparison studies use test databases[23] to measure the accuracy of the concentrations predicted by these models relative to concentrations measured with monitors in the test domain.

[23] These databases (e.g., Martin's Creek) are available from EPA at http://www.epa.gov/ttn/scram/dispersion_prefrec.htm#aermod.

In the development and evaluation of regulatory models, field data are collected in experiments designed around specific model inputs and algorithms. For example, meteorological inputs used to characterize atmospheric stability and plume rise have evolved from the relatively simple Pasquill-Gifford windspeed, sky cover, and time of day to the more complex inputs required by AERMET. Similarly, evaluation of algorithms for plume rise, dispersion, building downwash, and terrain effects are based on experiments designed to allow simple comparisons (often using intentional tracers) of measurements and observations.

The comparison study reported herein is not designed to compare the relative performance of AERMOD and ISCST3 in a general sense, but instead is intended to establish continuity from ARB's 2004 modeling analysis, through the RRAMP study which resulted from that analysis, to the present. As discussed above, the ISCST3 model was used by ARB in the original dispersion modeling analysis for this rail yard, while AERMOD is currently EPA's (and ARB's) preferred dispersion model. The RRAMP study was designed to evaluate the ability of upwind-downwind concentration measurements in the extreme near-field to confirm expected changes in emissions over time from a large number of dynamic sources. The comparisons here between measured and predicted concentrations accept the model formulations as the best currently available. However, it is recognized that the dynamic nature of rail yard operations introduces substantial uncertainty in the comparability of results during different periods. In particular, the hour-to-hour changes in the locations and magnitudes of emissions within the yard can yield substantial variability in measured concentrations at any single monitoring station even though total yard emissions may be near-constant.

Models Used for Sensitivity Analysis – To determine the effect that choice of model and model parameters would have on predicted concentrations, the two dispersion models used in the present study, ISCST3 and AERMOD, were run in both rural and urban modes. Dispersion coefficients are used in both of these dispersion models to characterize the land use (which affects dispersion) over which pollutants are transported.

The models were run without use of the Ozone-Limiting Method (OLM) or the Plume Volume Molar Ratio Method (PVMRM). The result of this approach is that the model treats all of the NOx that is emitted as if it were converted to NO_2. Multiplying the NO_2 model outputs by the molecular weight ratio of NO to NO_2 (i.e., 30/46) was used to produce the modeled NOx (as NO) concentrations presented in this report. By treating all measured and modeled NOx as a single species (i.e., NO), the models' predictions of dispersion could be compared with NOx measurements (expressed as NO) without the complication of the completeness of the conversion reaction.

The urban coefficients generally result in better dispersion, and lower maximum concentrations, than the rural coefficients.[24]

[24] This is because urban coefficients represent higher surface roughness than that of rural coefficients, which induces better dispersion.

4.2 Emissions

The ARB Roseville Study developed DPM emission estimates for the 1999-2000 period for each type of locomotive activity within the rail yard, and assigned them to appropriate source locations within the yard for purposes of modeling. More detailed and automated procedures have been developed by UPRR in the course of its work supporting ARB's more recent analyses of other rail yards. These detailed procedures have been applied to DPM emissions from locomotive train and service activity data at the Roseville rail yard for 1999-2000, 2005, 2006, 2007 and 2008 (Ireson, 2009). The same procedures were applied to calculate NOx (as NO_2) emissions for these four one-year periods. These emissions estimates were processed in the same manner as the analyses[25] prepared to support the 2005 ARB rail yard MOU to produce spatially and temporally resolved emission inputs for modeling. The emissions estimates reflect changes over time in the number and types of trains, the distribution of locomotive models and emission control technologies, locomotive service and maintenance activity, and fuel quality.

For the four RRAMP monitoring periods, monthly, day of week, and diurnal activity profiles were developed for train activity. Service and shop release data for these periods were used to develop monthly activity profiles for the RRAMP season months of June through October each year.

Scenarios for Sensitivity Analysis – Four emission scenarios were evaluated in the sensitivity analysis. Hourly emissions were estimated (based on actual activity data) for each activity area for each hour of each day of the week; annual average emission rates were then calculated for each activity area. This resulted in four emission scenarios, one for each year in the RRAMP monitoring period: 2005 through 2008. In general, the long-term annual emission inventories for the different source areas of the rail yard are considered to be more complete and accurate than the short-term hourly estimated emissions for the different source areas.

4.3 Receptor Locations

Several grids were used to locate receptors within the overall modeling domain. The modeling domain consisted of a 20 km x 20 km area centered on the centroid of the Roseville Rail Yard. Within that domain, a fine-resolution Cartesian receptor grid using 50 m spacing was developed to cover the area close to the yard (receptors located within 400 meters of the yard boundaries), which includes the locations of the four RRAMP monitoring locations. A coarse-resolution Cartesian receptor grid (200–500 m spacing) covered the rest of the domain (i.e., from 400 meters out to 20 km). Discrete receptors represented the four RRAMP monitoring sites, and a tier of four rows of closely spaced receptors (i.e., 25 m between rows and between receptors) was placed along the downwind (i.e., northwest) rail yard boundary (i.e., extended from the boundary out to

[25] See, e.g., Sierra Research, *Toxic Air Contaminant Emission Inventory and Dispersion Modeling Report for the Los Angeles Transportation Center*, Appendices A, J, and K. January 2007

100 meters) because maximum concentrations frequently occur near the boundary. Finally, a 10-meter spacing grid that extended 50 meters parallel to the nearest boundary by 40 meters perpendicular to the same boundary was placed around each of the four monitor locations. Two of these four finest grids, those around the Denio and Church monitors, were used to evaluate the sensitivity of model predictions to the precise location of the RRAMP monitoring stations.

4.4 Meteorological Data

The meteorological data used in the Roseville portion of the 2004 ARB study used vector-averaged wind data. Because the dispersion models require the use of scalar-averaged wind data, questions arose about the validity of the conclusions in the ARB study.

To assess the impact that this difference in wind data type might have on modeling results, all modeling performed for the present study was conducted twice—once using meteorological data collected by ARB from the nearby Roseville meteorological monitoring station[26] (vector-averaged data), and once using data collected onsite (scalar-averaged data).

Concurrent vector-averaged wind data from the ARB Roseville station were obtained and, along with data from the RRAMP on-site meteorological station, were processed into ISCST3- and AERMOD-ready files. For both sets of surface data, model inputs were prepared for each entire year; a second set of model inputs were prepared that were limited to the RRAMP season monitoring periods (mid-June to mid-October,10PM – 5AM PST) (Campbell and Fujita, 2008). These periods were identified during the RRAMP data analysis as having the most consistent wind direction for detecting upwind-downwind concentration differences presumed to be attributable to rail yard emissions (i.e., light to moderate winds from the southeast).

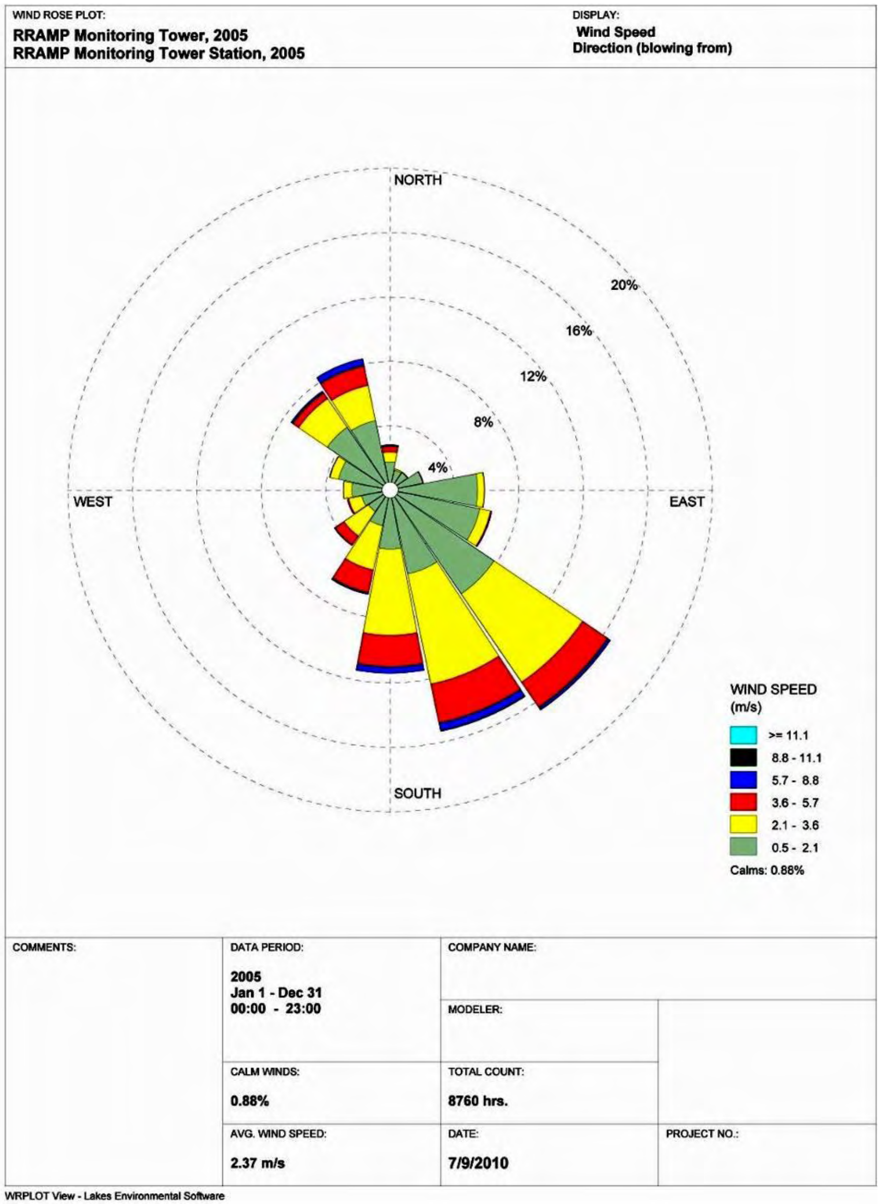
Wind roses for each of the four years of the RRAMP study are shown in Figures 3-6. Wind roses for the limited hours used to compare measurements with modeled predictions are shown in Figures 7-10. Aside from a slight shift in direction (about 22.5°), the two data sets show reasonably good correlation.

Meteorological Data for Sensitivity Analysis – The modeling for the sensitivity analysis used a full year of data for each scenario that was run. Two sets of data were used: meteorological data collected by ARB from the Roseville meteorological station, and data collected at the monitoring towers located onsite.

[26] The ARB Roseville monitoring station is located at 151 North Sunrise Avenue, approximately 1.5 miles east of the rail yard.

Figure 3 – Wind Rose, Annual (2005)

Onsite



Roseville Station

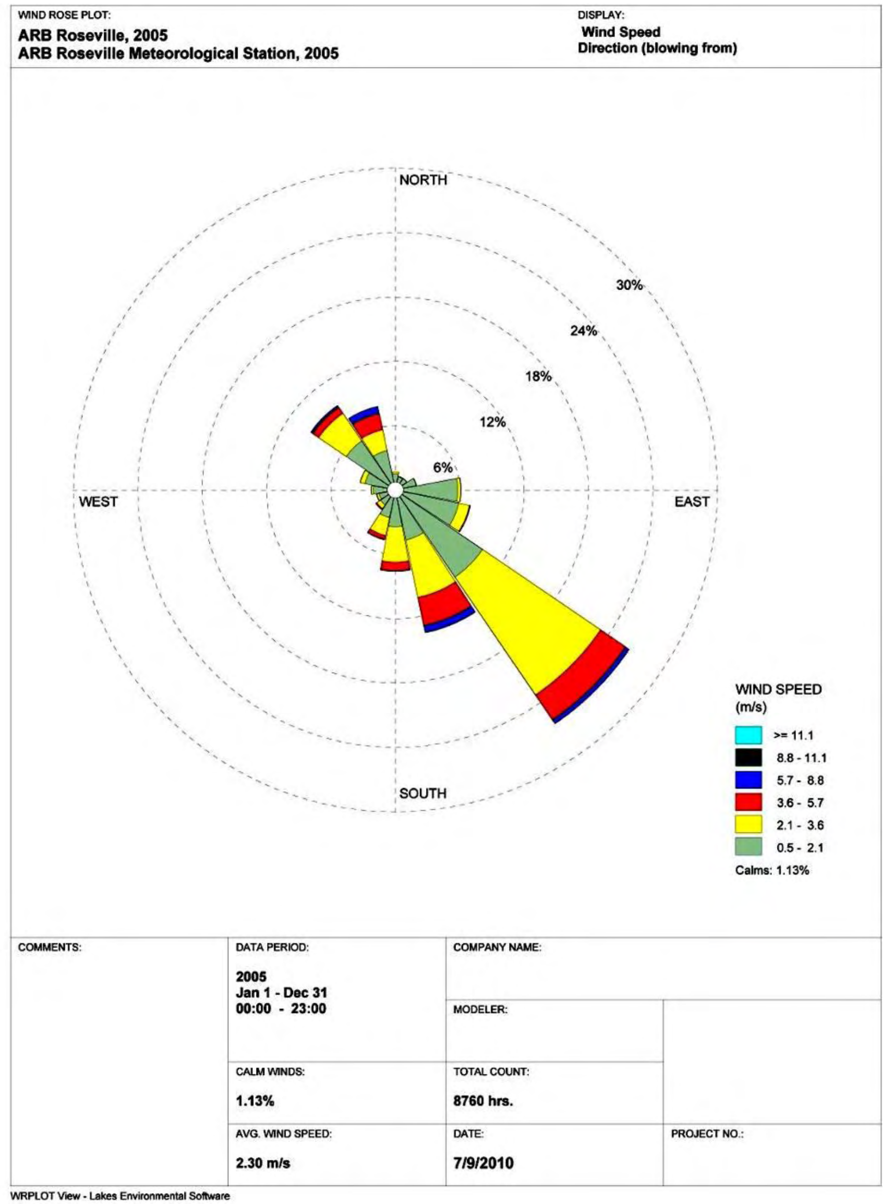
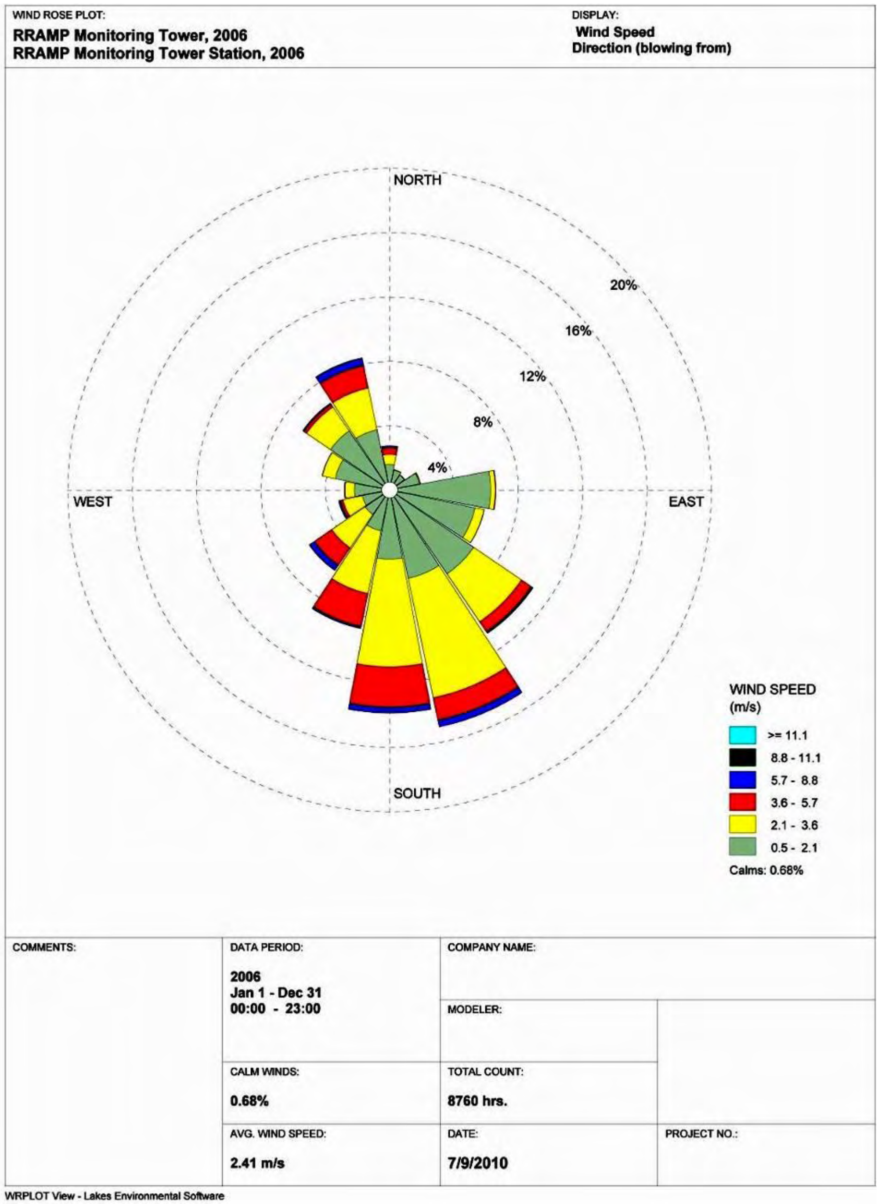


Figure 4 – Wind Rose, Annual (2006)

Onsite



Roseville Station

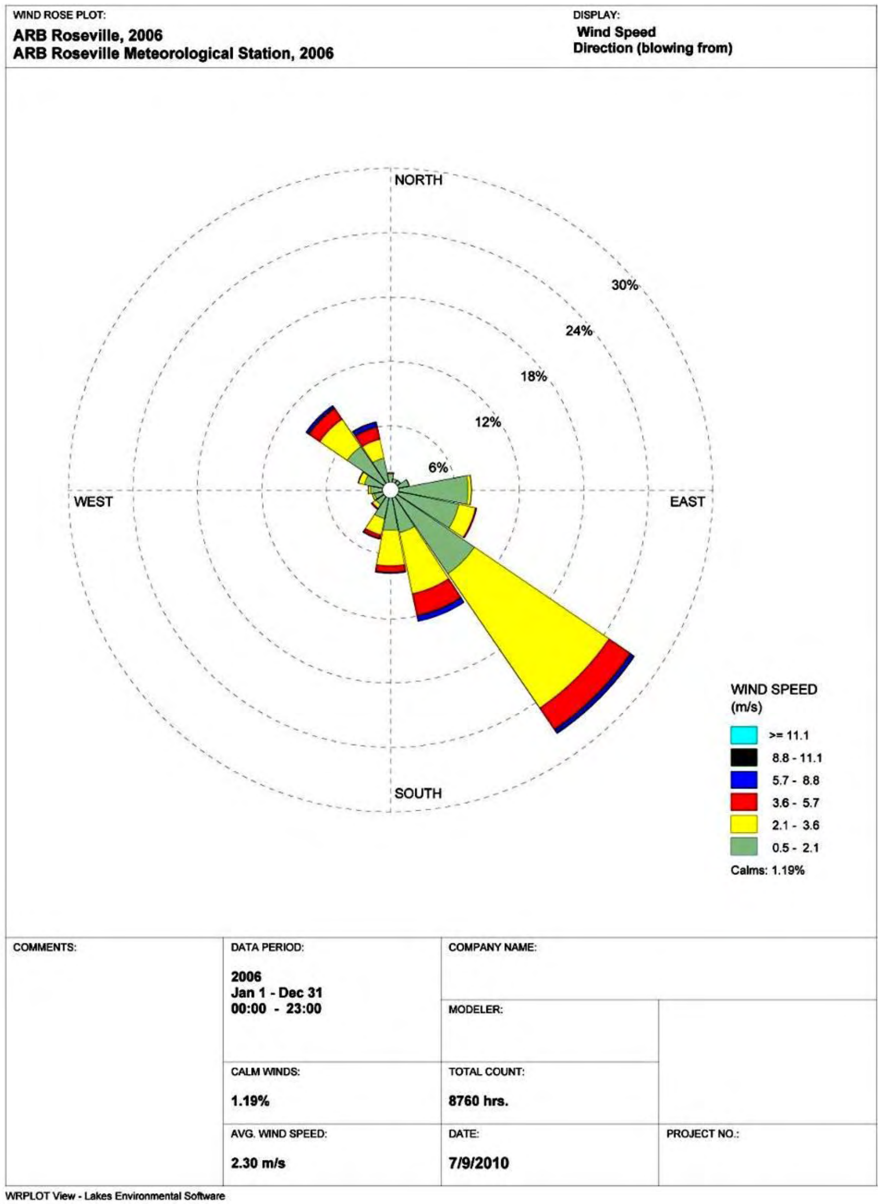
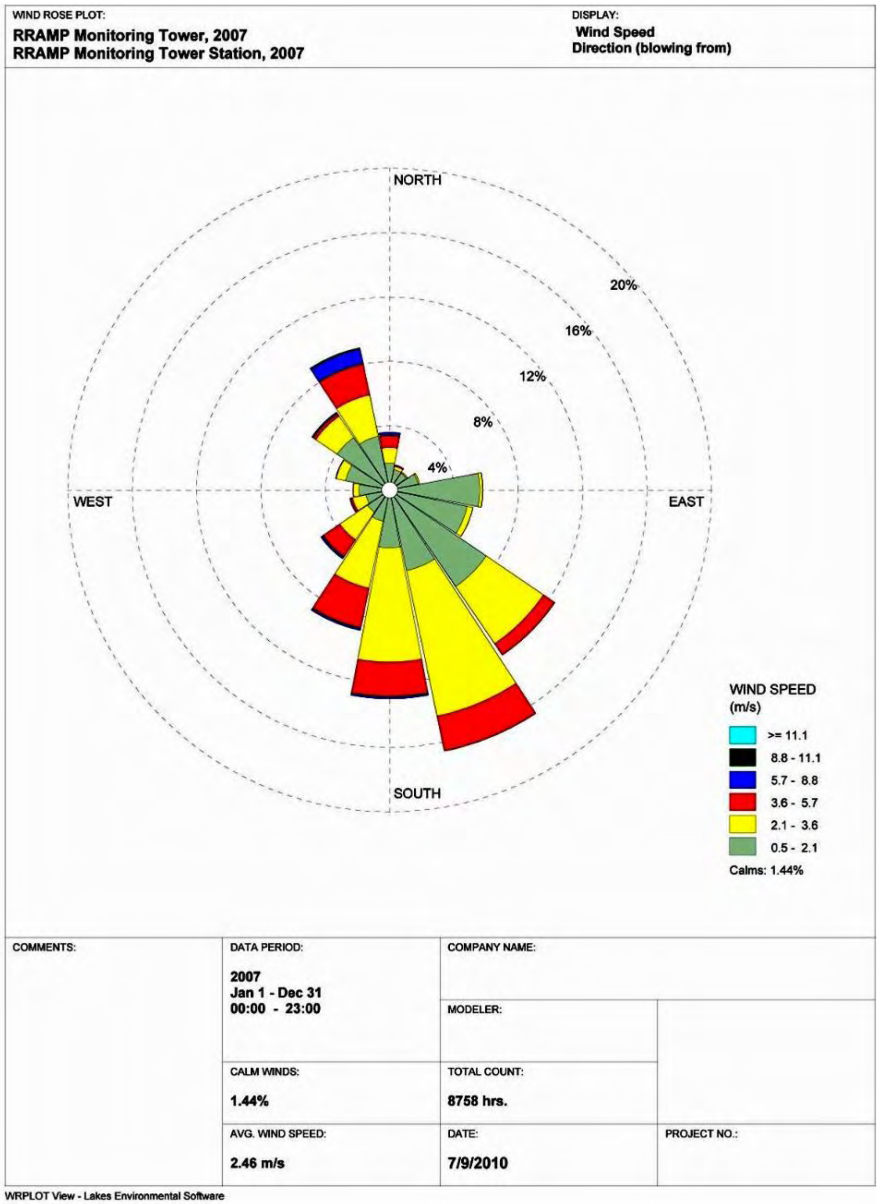


Figure 5 – Wind Rose, Annual (2007) (onsite data)

Onsite



Roseville Station

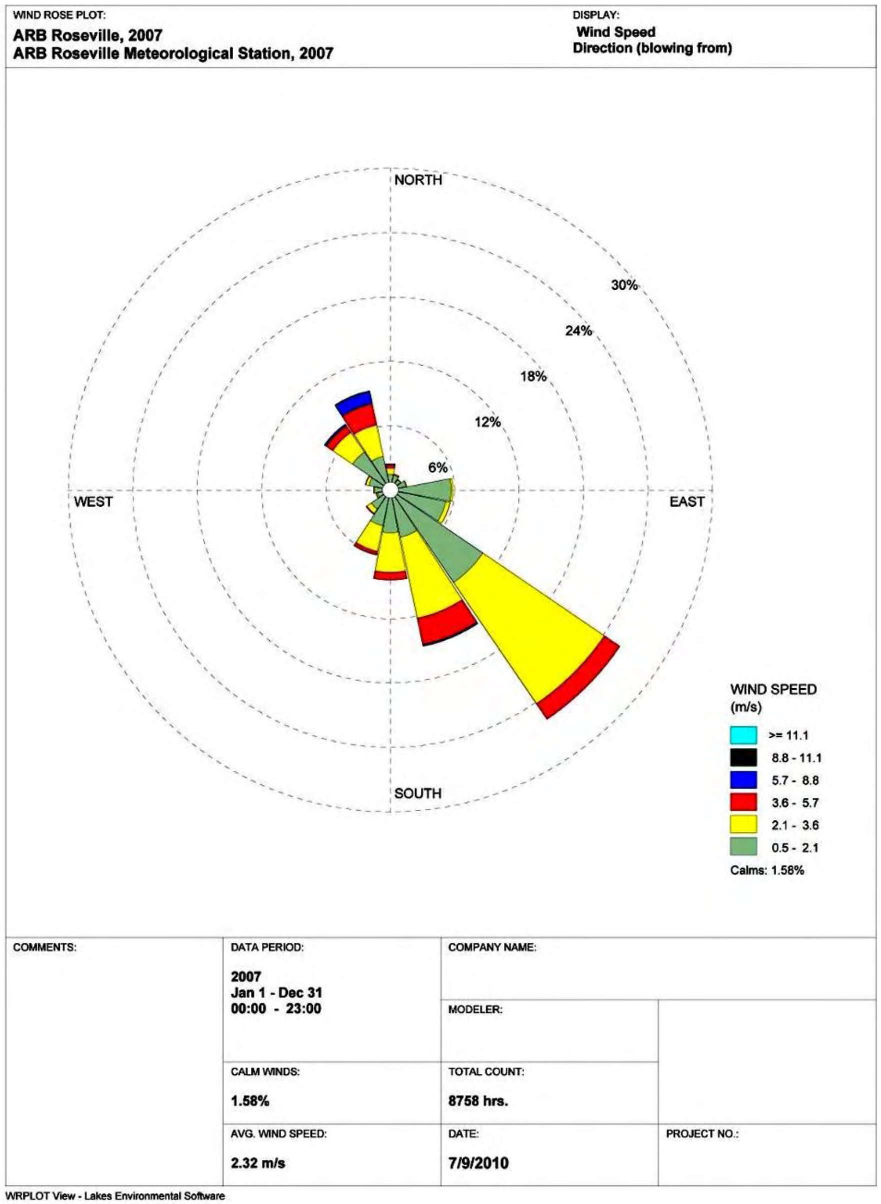
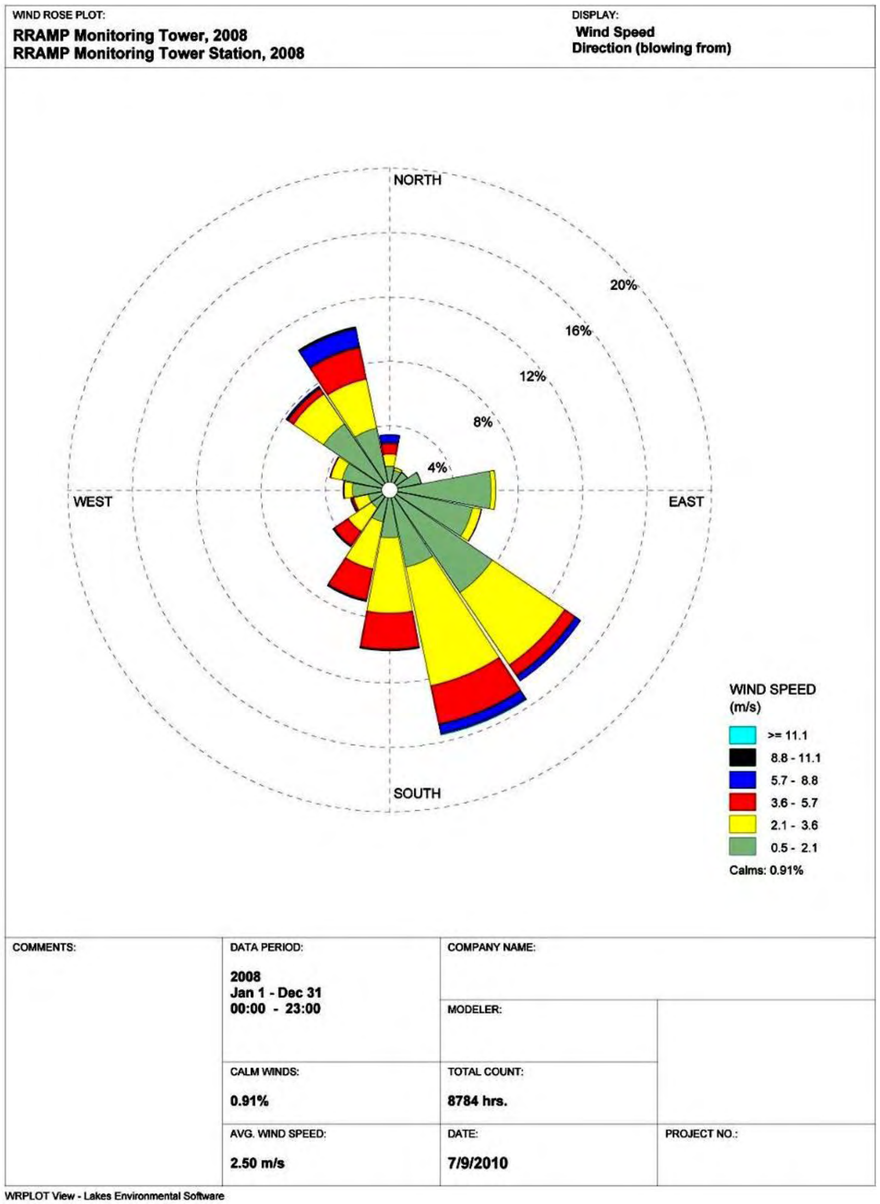


Figure 6 – Wind Rose, Annual (2008) (onsite data)

Onsite



Roseville Station

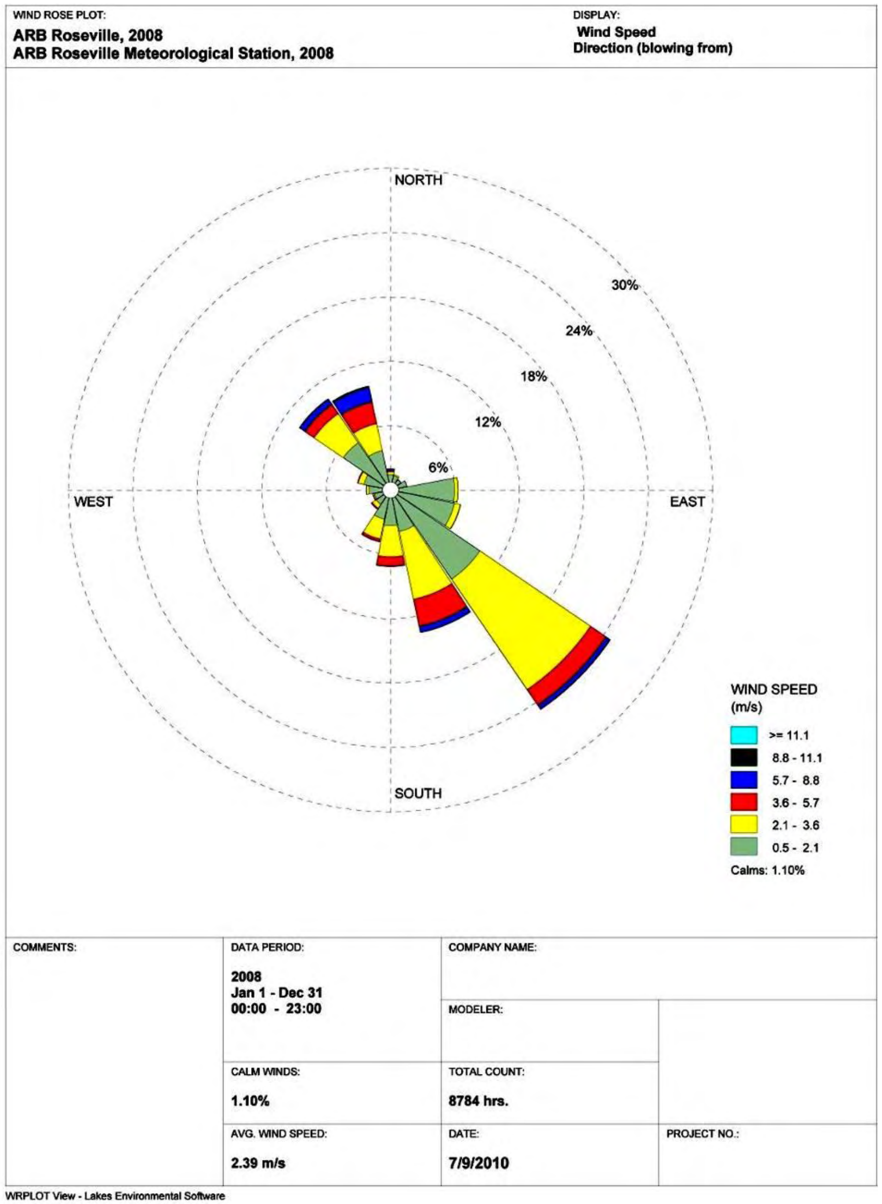
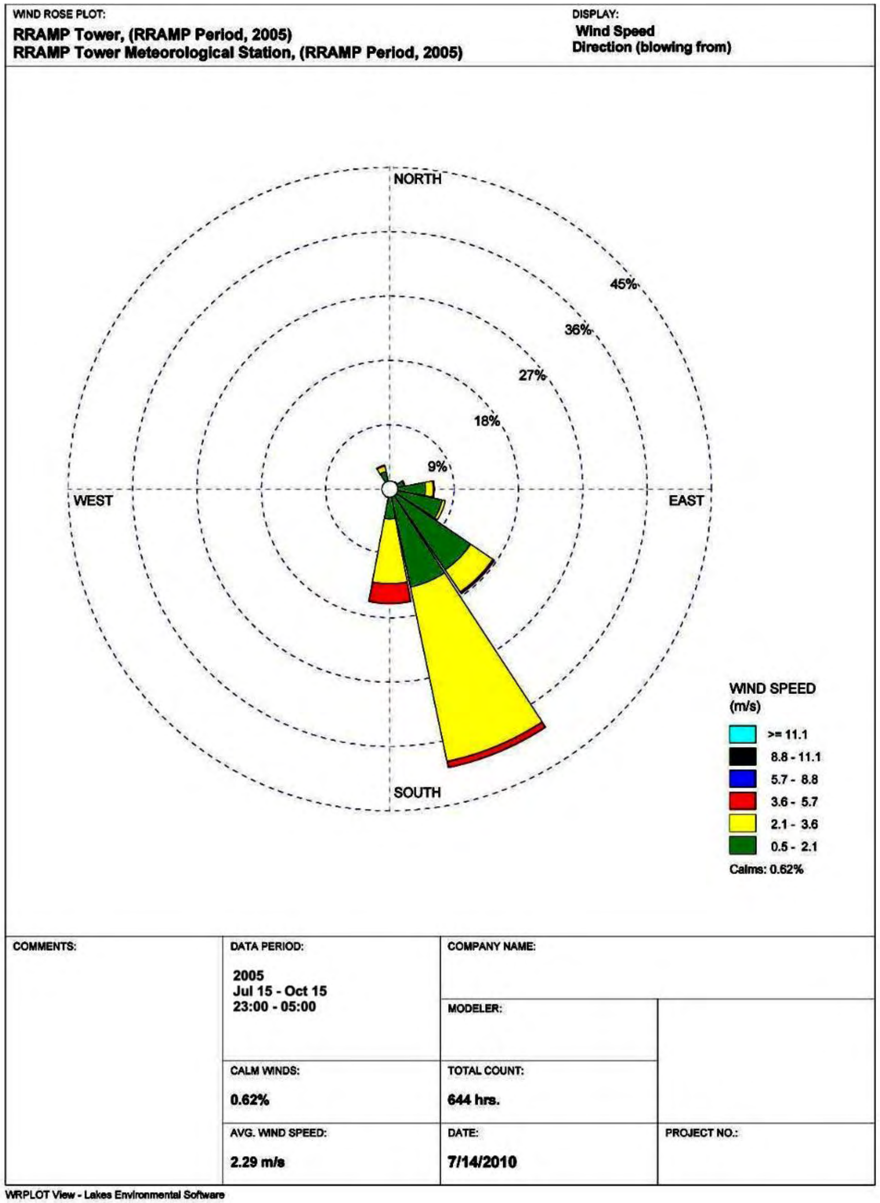


Figure 7 – Wind Rose (RRAMP Period 2005, 10:00pm - 5:00am)

Onsite



Roseville Station

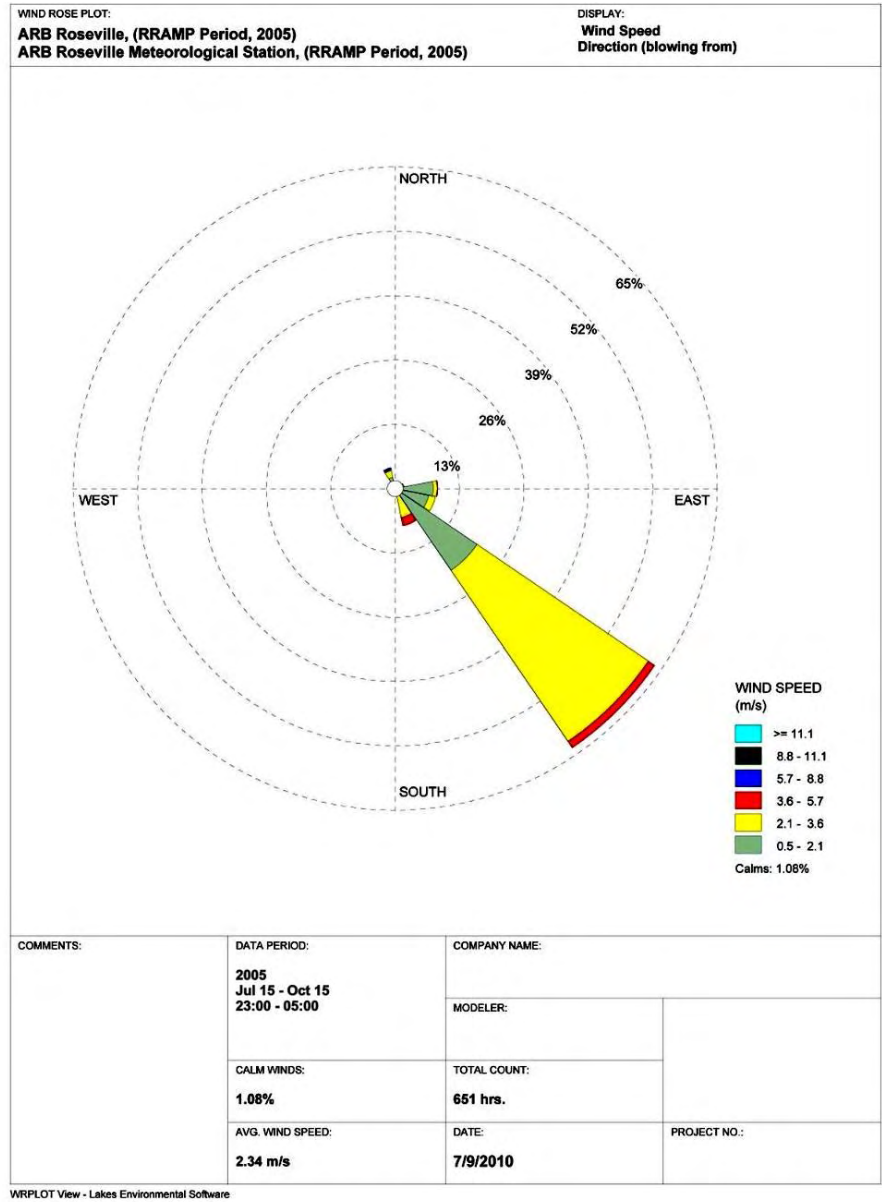
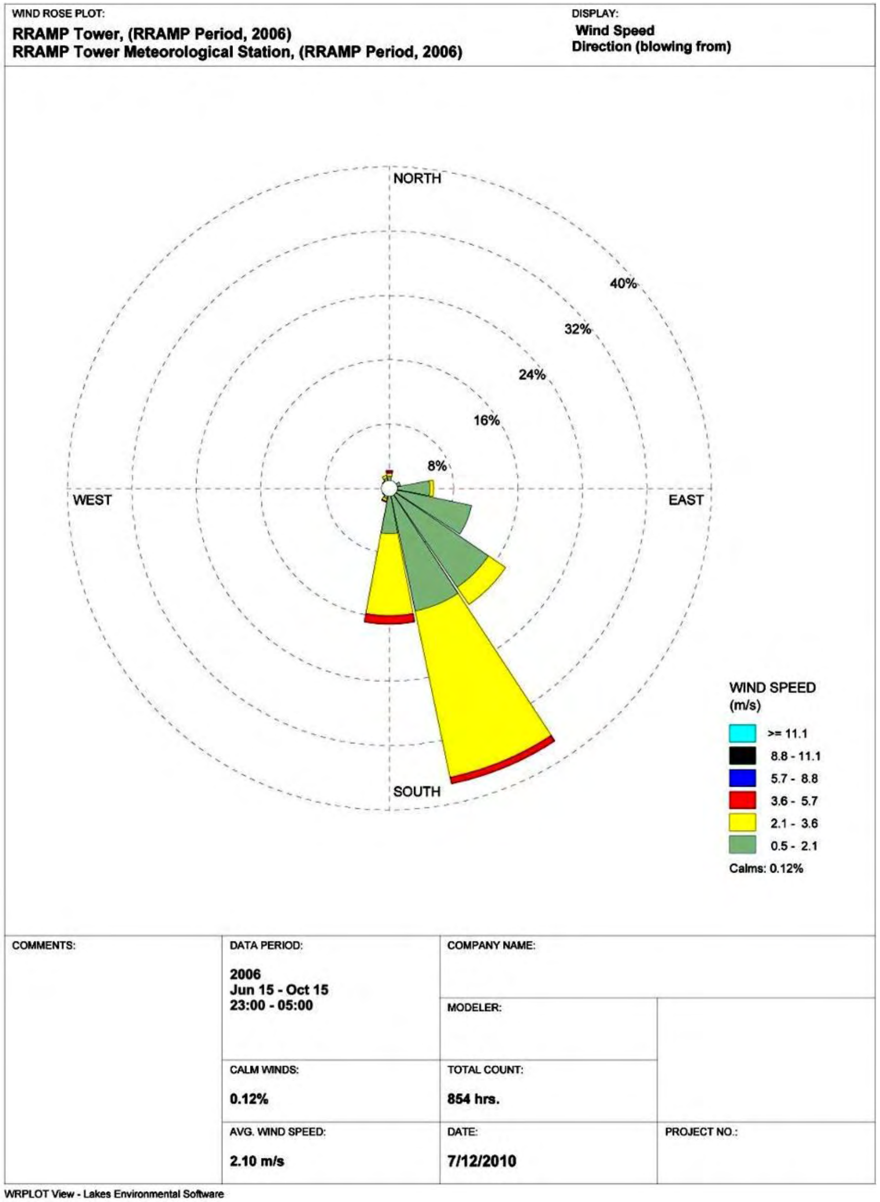


Figure 8 – Wind Rose (RRAMP Period 2006, 10:00pm - 5:00am)

Onsite



Roseville Station

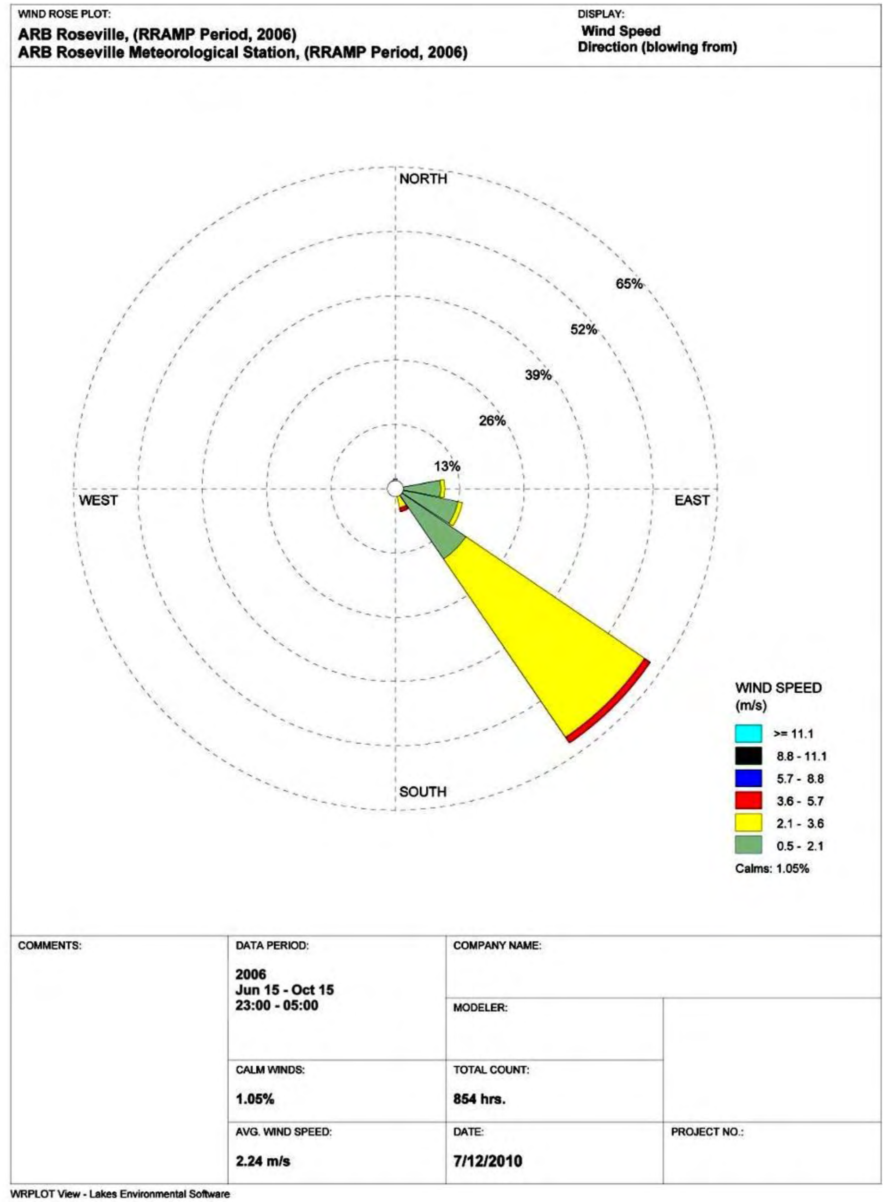
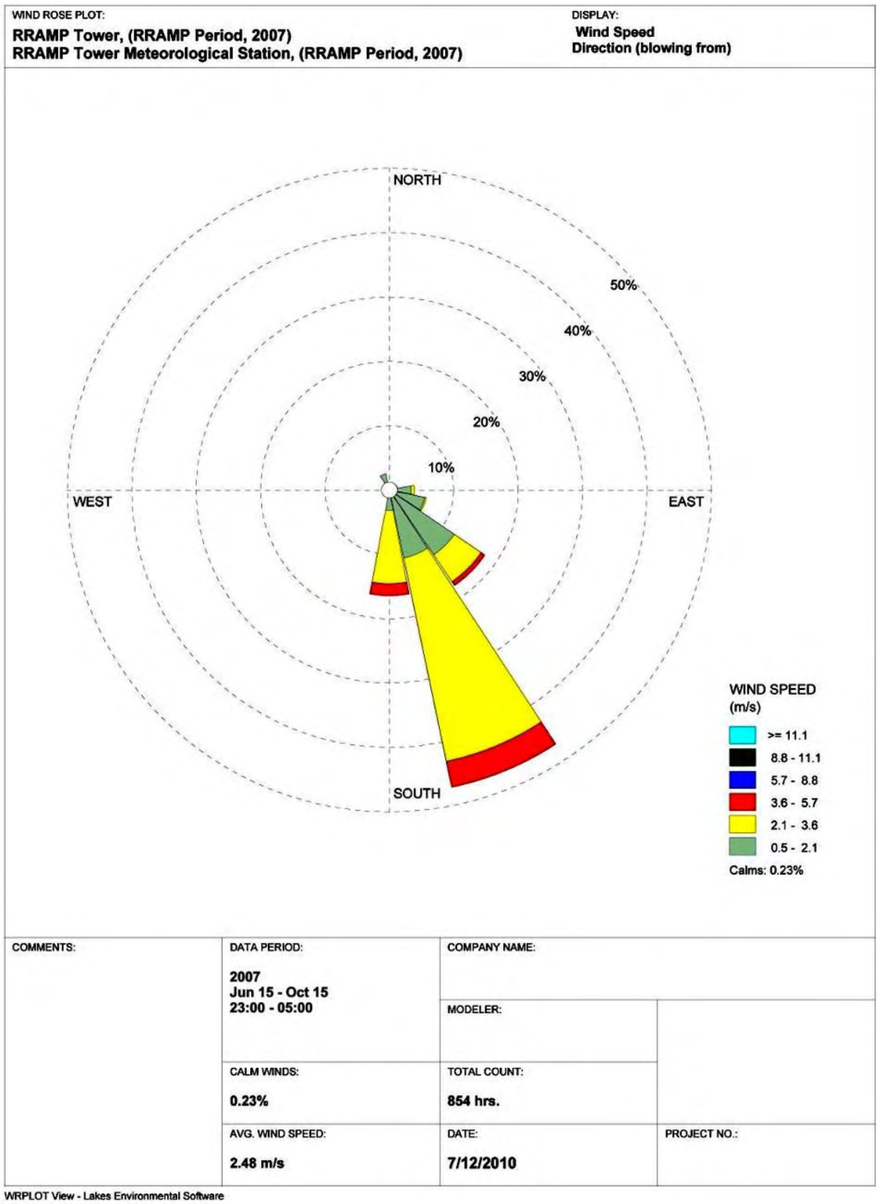


Figure 9 – Wind Rose (RRAMP Period 2007, 10:00pm - 5:00am)

Onsite



Roseville Station

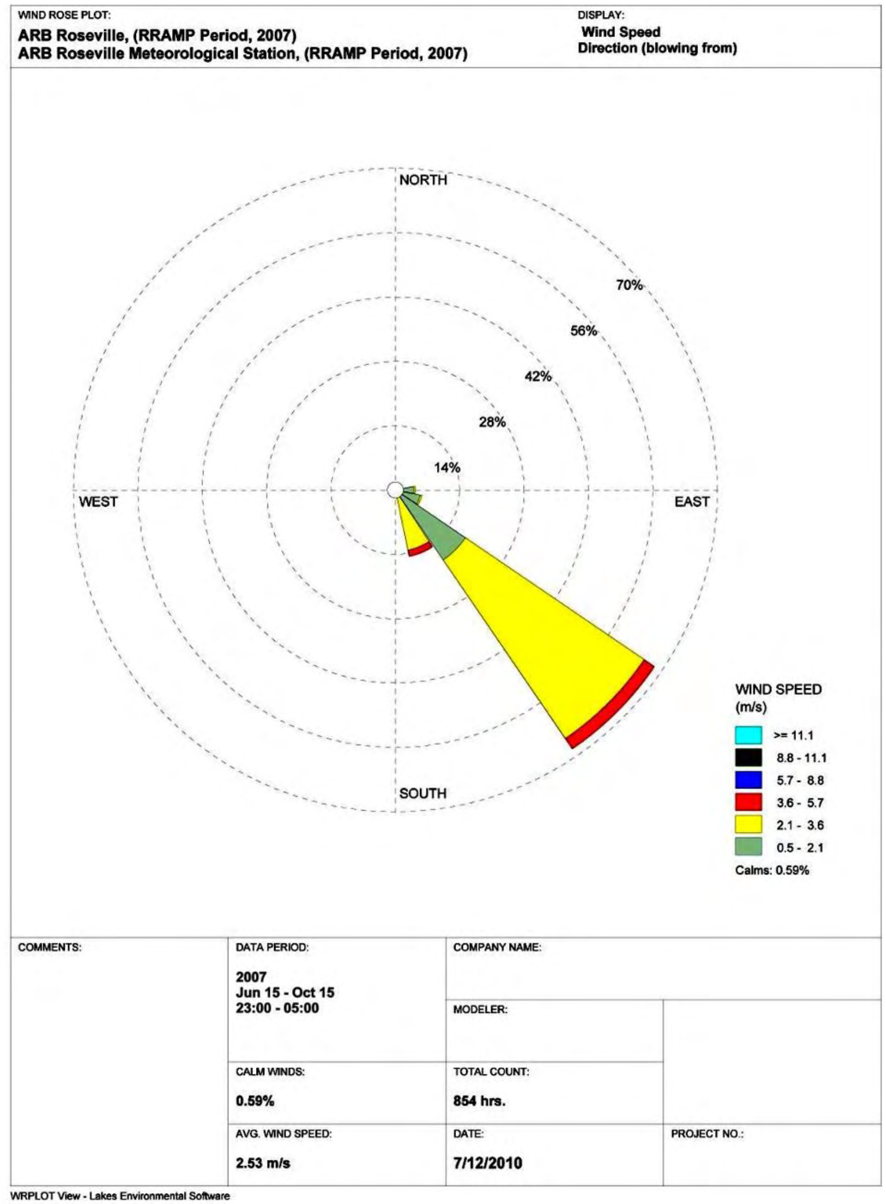
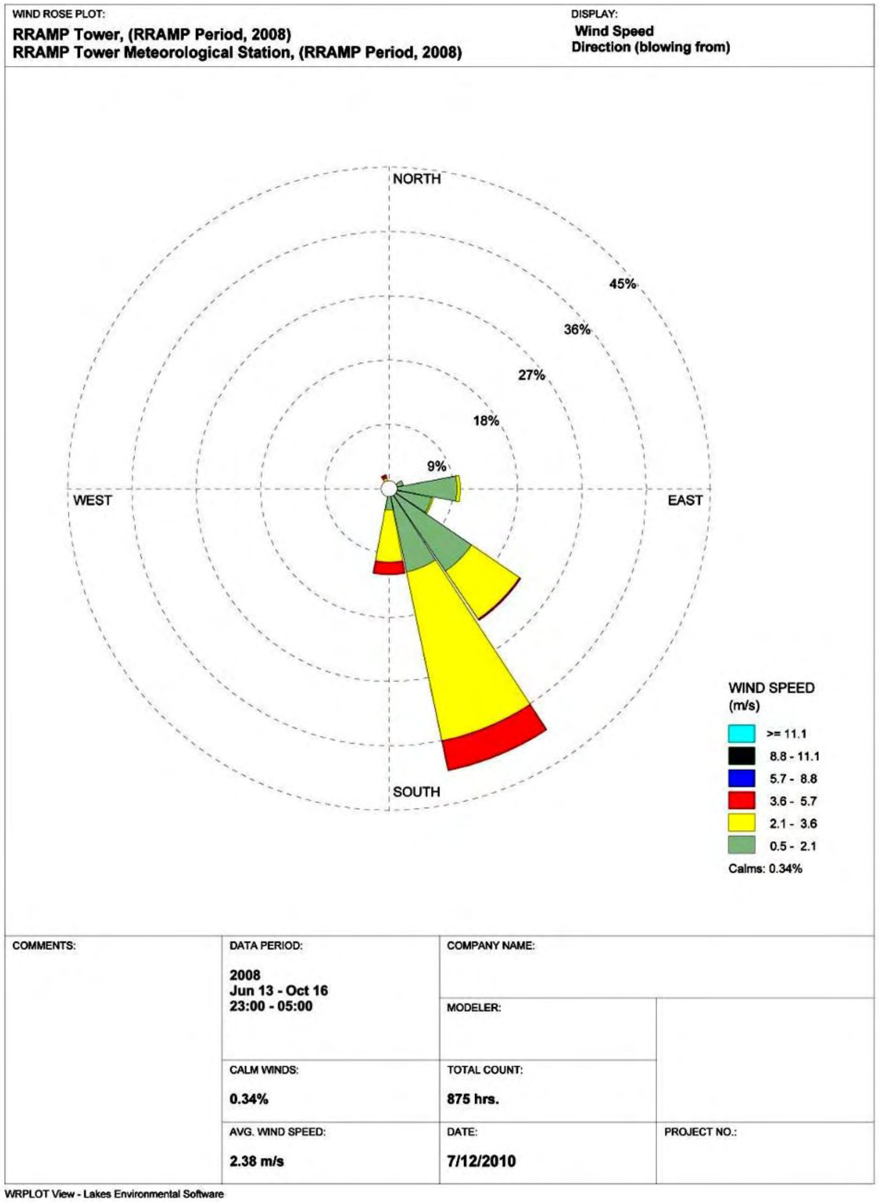
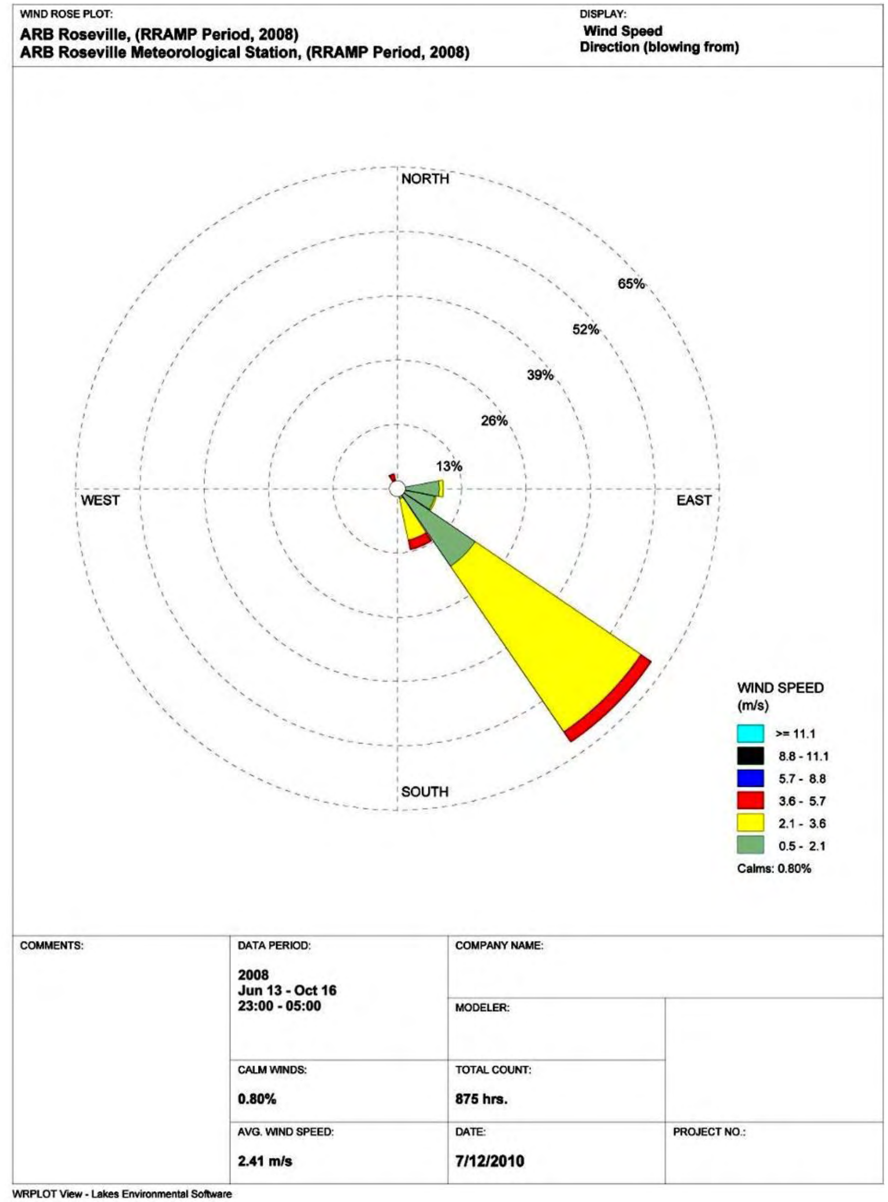


Figure 10 – Wind Rose (RRAMP Period 2008, 10:00pm - 5:00am)

Onsite



Roseville Station



5. ANALYSIS

5.1 Model Sensitivity Analyses

Results from the simulations described above were analyzed to determine the variation in calculated pollutant concentration when different models and modes, urban and rural dispersion coefficients, and two meteorological data sets are used.

Choice of Meteorological Data – Meteorological data were collected at the rail yard at the same time air quality monitoring data were collected as part of RRAMP. The data were collected with sensors on a tower inside the yard that complied with USEPA regulatory requirements for PSD monitoring sites. These meteorological and related data were preprocessed to produce the required inputs for both ISCST3 and AERMOD. For ISCST3, the meteorological tower wind and temperature data were organized into the required format using the PCRAMMET ISCST3 preprocessor program. For AERMOD, the data were preprocessed using the AERMET preprocessor program. Concurrent upper air temperature data as a function of altitude from Oakland International Airport were used to determine atmospheric stability in this preprocessing.

Meteorological data for the ARB Roseville monitoring station were obtained from ARB. These data were preprocessed in the same manner as the RRAMP data described above.

The vector-averaged Roseville monitoring data were compared with the scalar-averaged RRAMP monitoring data in a series of comparisons. Figures 11-14 show how the two meteorological data sets compared in their predictions of annual average dispersion using AERMOD (Urban mode). Figures 15-18 present the same comparison using the ISCST3 model (Urban Mode). The emission scenarios used in these comparisons were the annual average emissions for each year in the RRAMP study period.

Figure 11 shows, for annual 2005 emission data and meteorology, the 0.5 $\mu g/m^3$ isopleth for DPM predicted by AERMOD (Urban Mode). Figures 12-14 show the same information using emission and meteorological data for 2006, 2007, and 2008. Figures 15-18 show the comparisons for DPM predicted by ISCST3 (Urban Mode) for 2005, 2006, 2007, and 2008. DPM was selected for illustration because of it was the pollutant of concern in the original, 2004 ARB modeling analysis, and Urban Mode was selected because it is expected to more accurately simulate dispersion near the rail yard than Rural Mode.

Figure 11 – Effect of Choice of Meteorological Data, Predicted 0.5 µg/m^3 Annual Average DPM Isopleth (AERMOD, Urban Mode), 2005 Annual Average Emissions

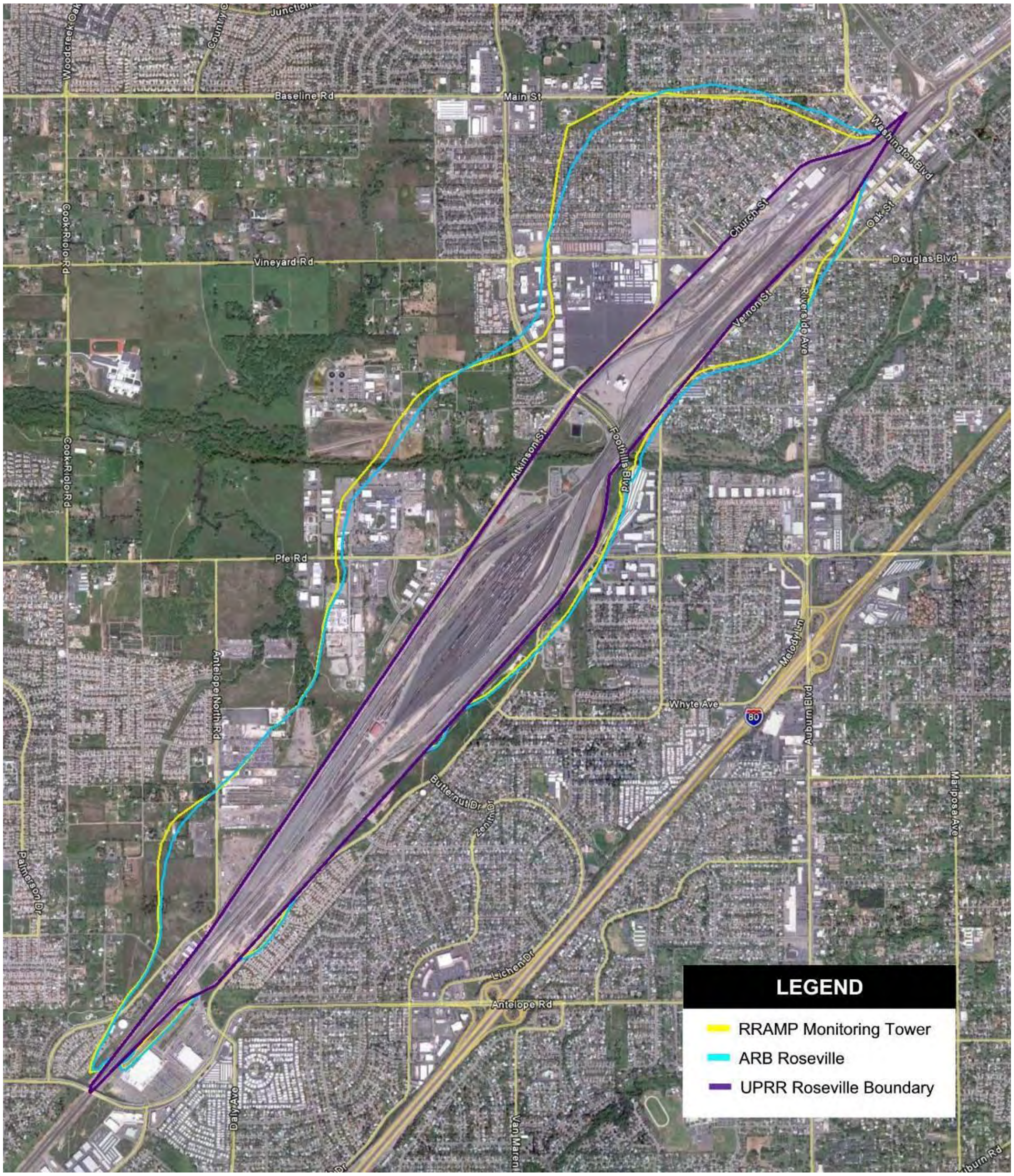


Figure 12 – Effect of Choice of Meteorological Data, Predicted 0.5 µg/m^3 Annual Average DPM Isopleth (AERMOD, Urban Mode), 2006 Annual Average Emissions

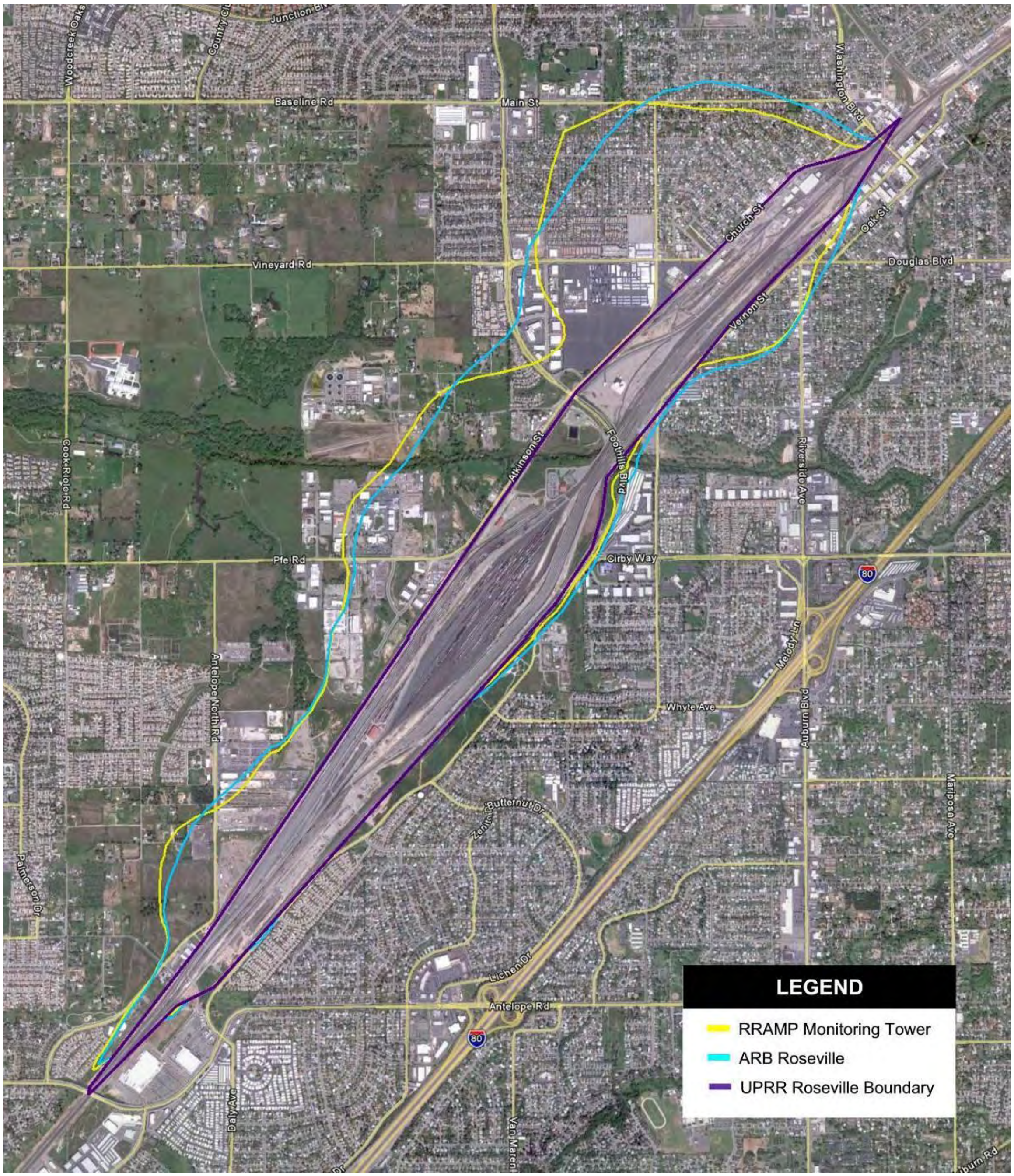


Figure 13 – Effect of Choice of Meteorological Data, Predicted 0.5 µg/m^3 Annual Average DPM Isopleth (AERMOD, Urban Mode), 2007 Annual Average Emissions

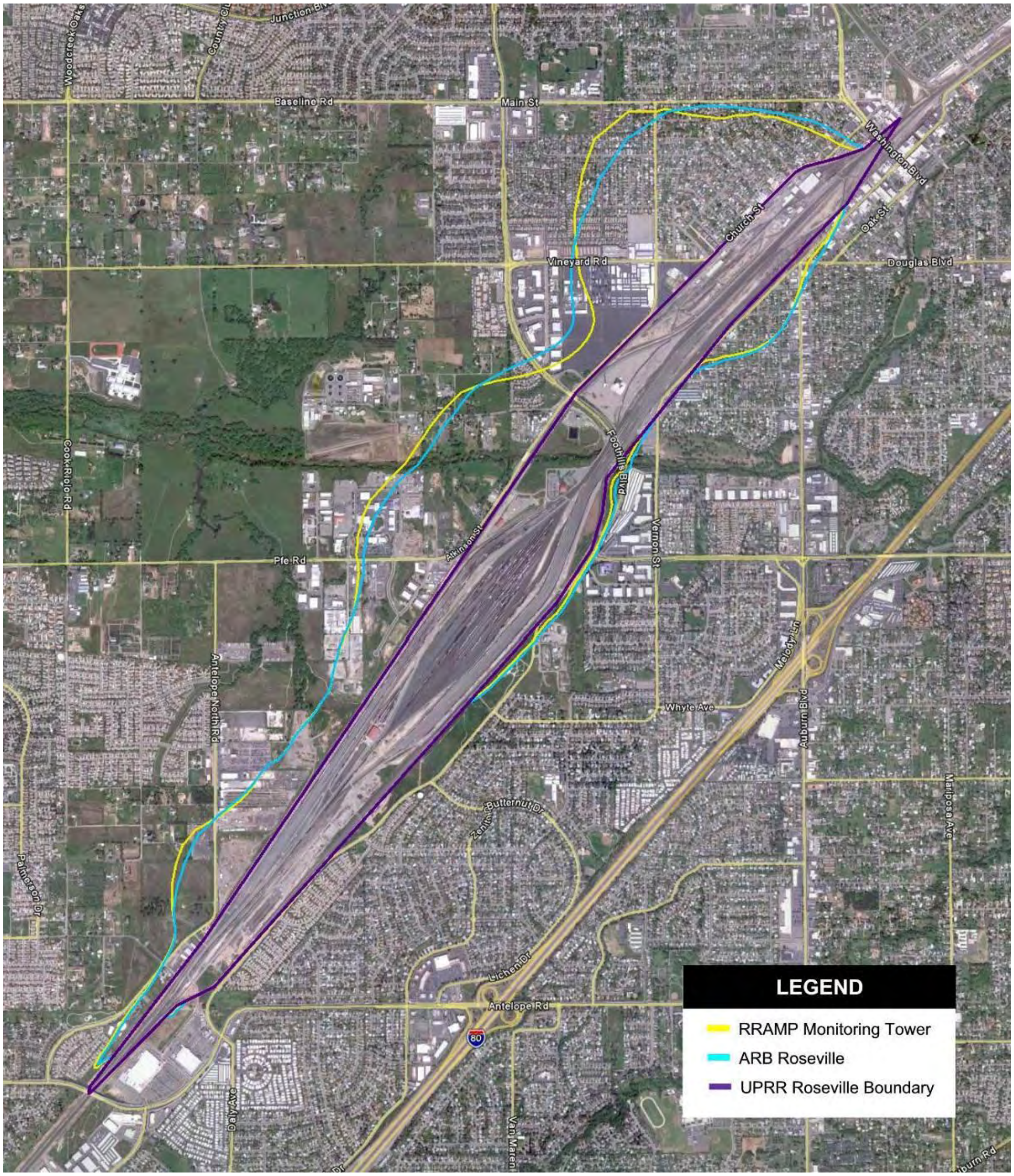


Figure 14 – Effect of Choice of Meteorological Data, Predicted 0.5 µg/m^3 Annual Average DPM Isopleth (AERMOD, Urban Mode), 2008 Annual Average Emissions

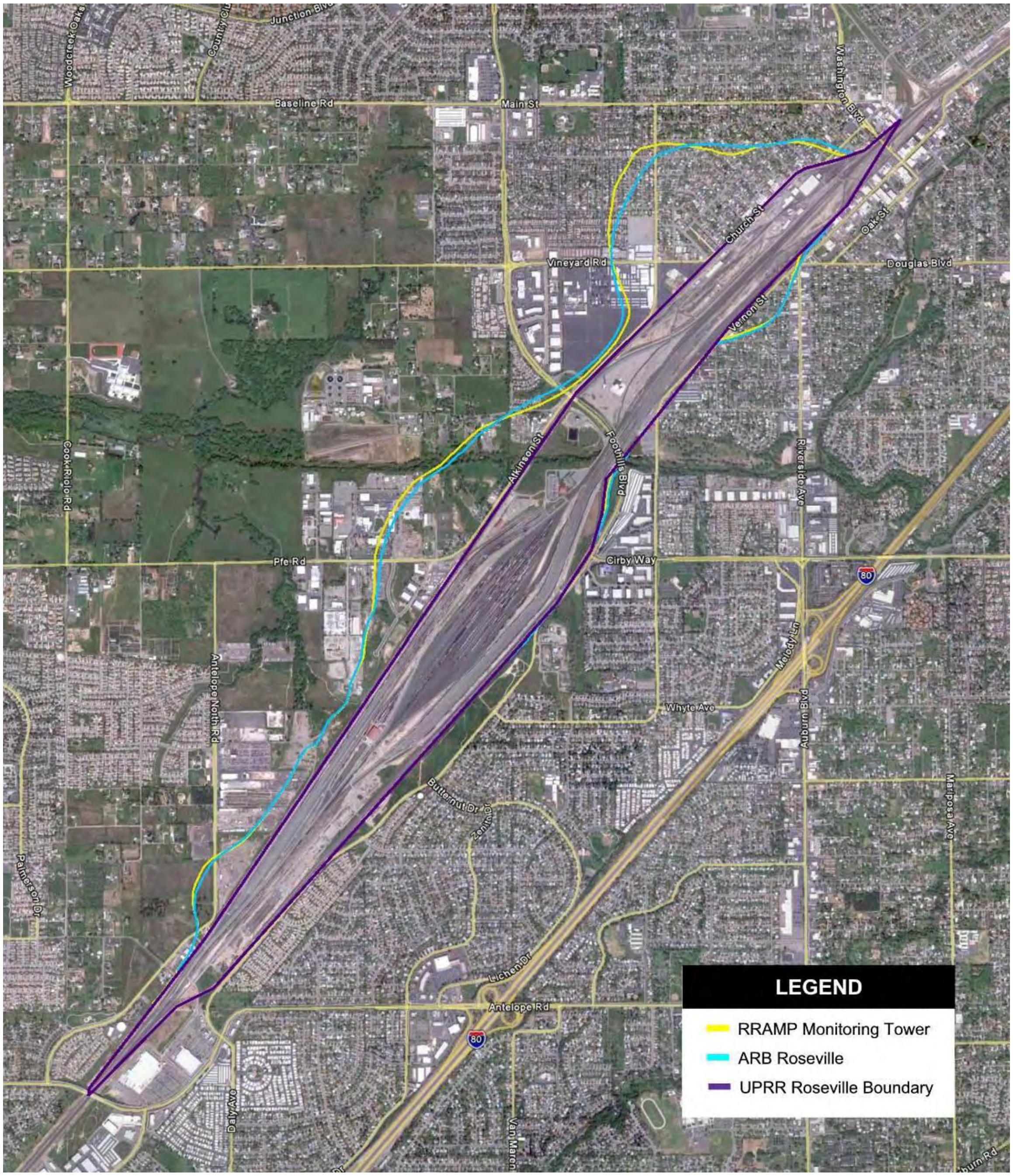


Figure 15 – Effect of Choice of Meteorological Data, Predicted 0.5 µg/m^3 Annual Average DPM Isopleth (ISCST3, Urban Mode), 2005 Annual Average Emissions

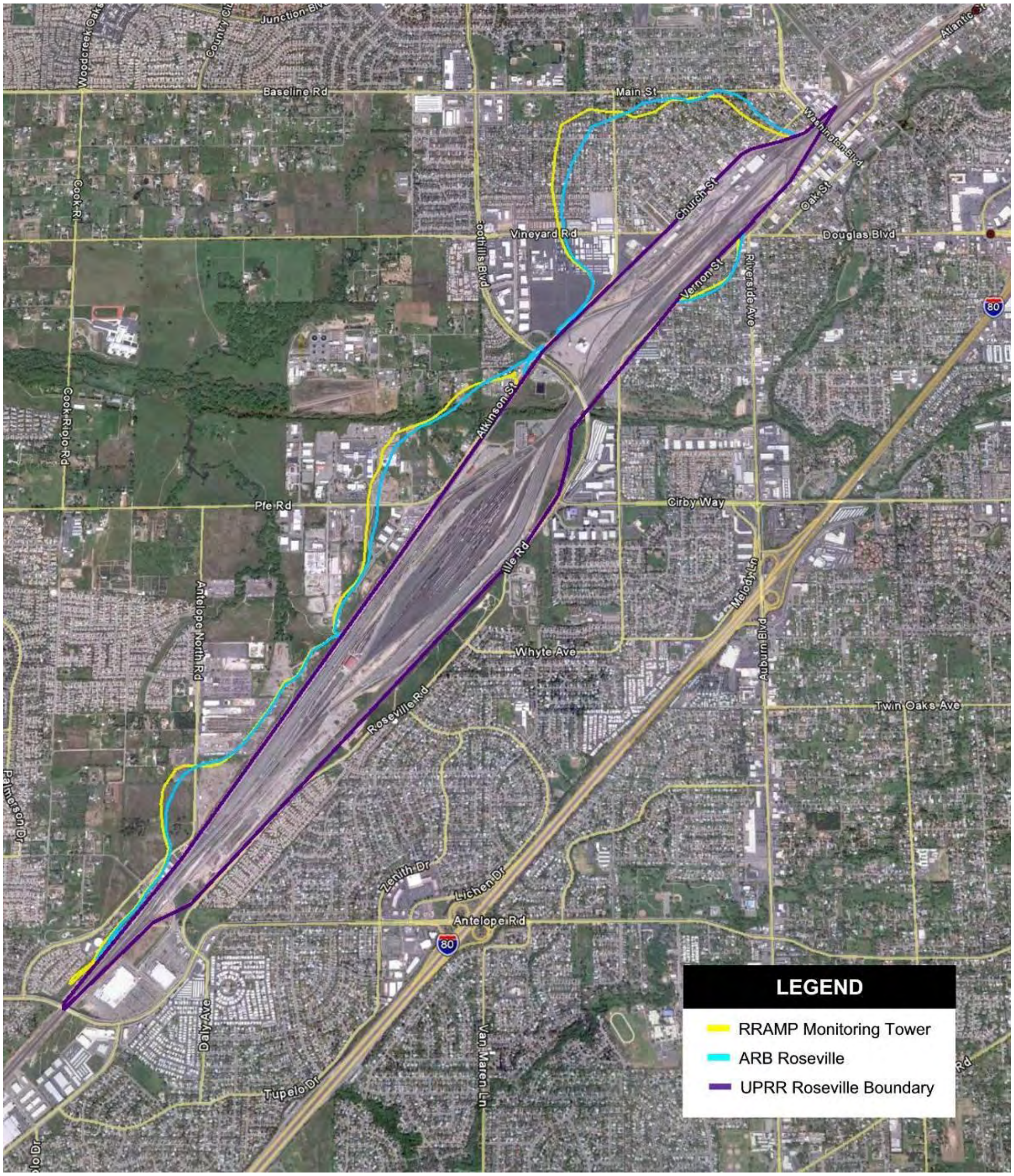


Figure 16 – Effect of Choice of Meteorological Data, Predicted 0.5 µg/m^3 Annual Average DPM Isopleth (ISCST3, Urban Mode), 2006 Annual Average Emissions

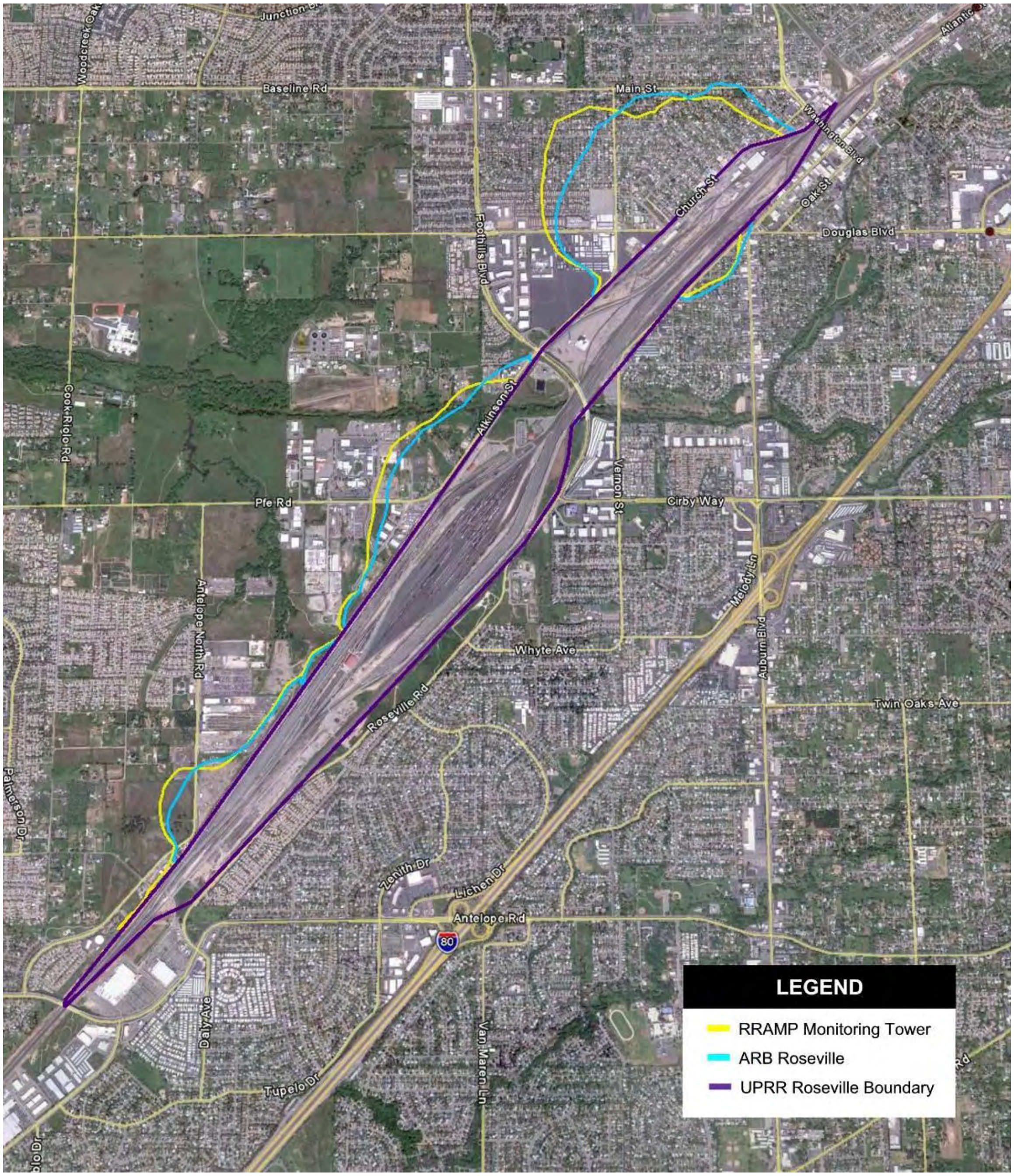


Figure 17 – Effect of Choice of Meteorological Data, Predicted 0.5 µg/m^3 Annual Average DPM Isopleth (ISCST3, Urban Mode), 2007 Annual Average Emissions

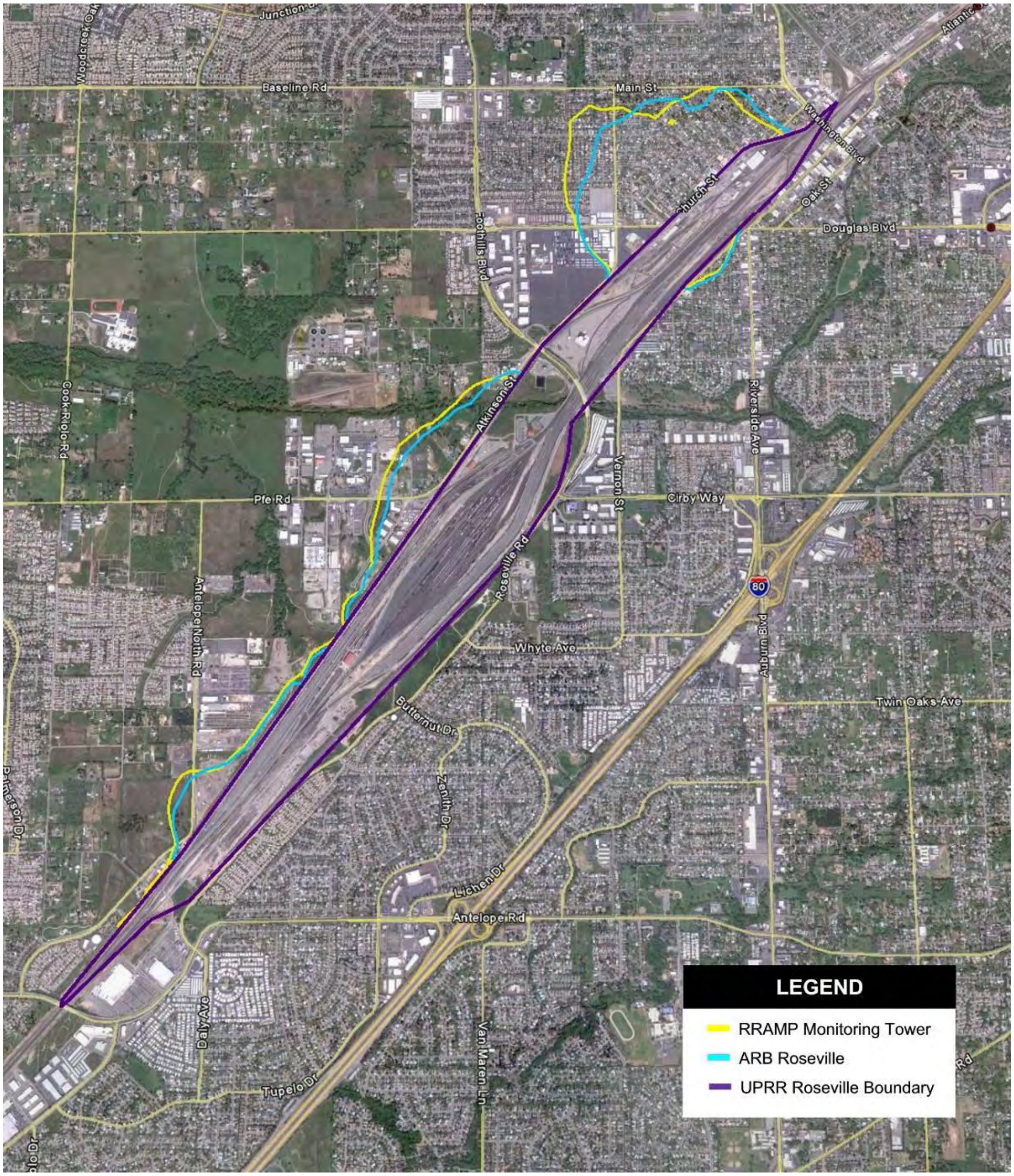
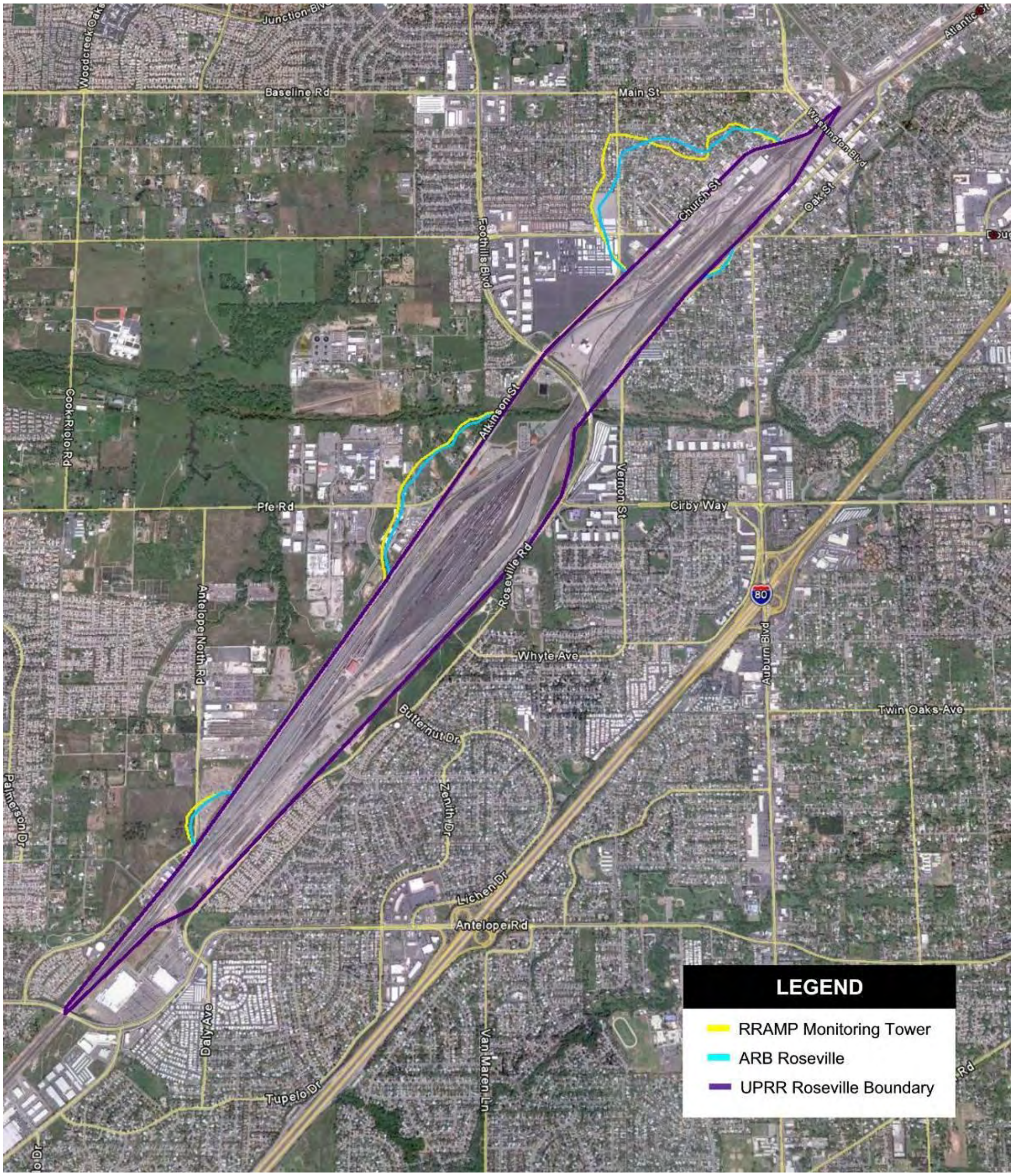


Figure 18 – Effect of Choice of Meteorological Data, Predicted 0.5 µg/m^3 Annual Average DPM Isopleth (ISCST3, Urban Mode), 2008 Annual Average Emissions



The purpose of comparing modeling results using the two meteorological data sets is to determine whether the use of vector averaging in the Roseville data affects the results. The standard procedure is to use scalar-averaging, which was used for the RRAMP tower data.

All eight figures show that the shape and position of the isopleths using the Roseville meteorological data and the onsite tower meteorological data are very similar. This observation is important because it indicates that the use of scalar- versus vector-averaged wind data has little effect on predictions of annual average concentrations in general. However, as discussed below in the spatial sensitivity analysis, a small difference in wind direction data can have a profound effect on the predicted concentration at a specific receptor.

Choice of Model – To determine how the choice of model and dispersion coefficients affects predicted concentrations, modeling runs were made using ISCST3 with urban coefficients (ISC URBAN), ISCST3 with rural coefficients (ISC RURAL), AERMOD URBAN and AERMOD RURAL. The onsite meteorological datasets for 2005 through 2008 were used for all runs. Model predictions were then compared numerically (comparisons of predicted concentrations at the two downwind monitoring points and clusters of receptors around those two points), graphically (comparisons of predicted concentrations over time), and spatially (comparisons of predicted isopleths).

The effect of choice of model on predicted impacts from the Roseville Rail Yard can be seen in Figures 19 through 22. Figures 19 and 20 show the predicted annual average DPM and NOx (as NO) impacts at Denio, respectively, while Figures 21 and 22 show the same information for Church. All four figures show the consistent substantial decrease in both DPM and NOx (as NO) RRAMP annual average concentrations during the four-year period regardless of the choice of model and mode. The magnitudes of the RRAMP seasonal NOx (as NO) and DPM decreases are shown in Tables 3 and 4, respectively.[27]

[27] Model-to-model comparisons are based on annual averages to obtain a more robust analytical base; model-to-measurement comparisons are based on RRAMP seasonal averages to correspond to the RRAMP monitoring seasons.

Figure 19 – Year to Year Trend, (DPM, annual average), Onsite Meteorological Data, Denio

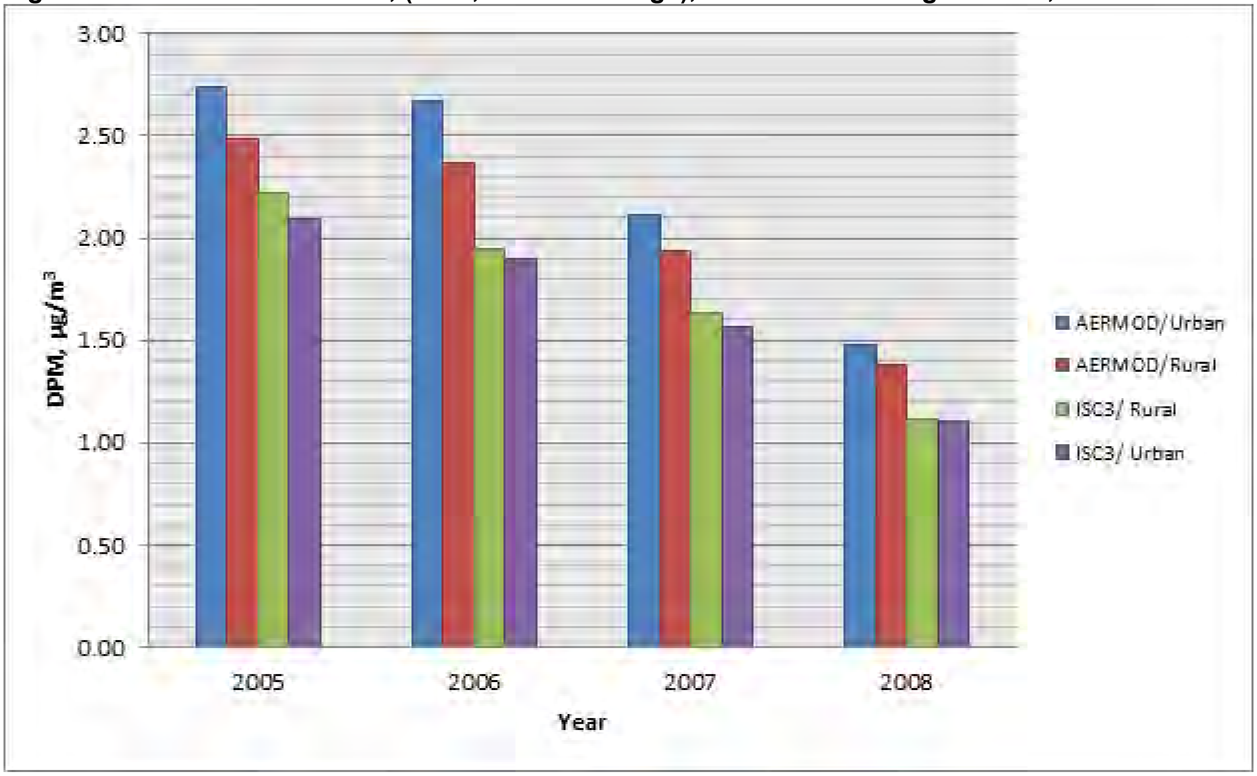


Figure 20 – Year to Year Trend, (NOx, as NO, annual average), Onsite Meteorological Data, Denio

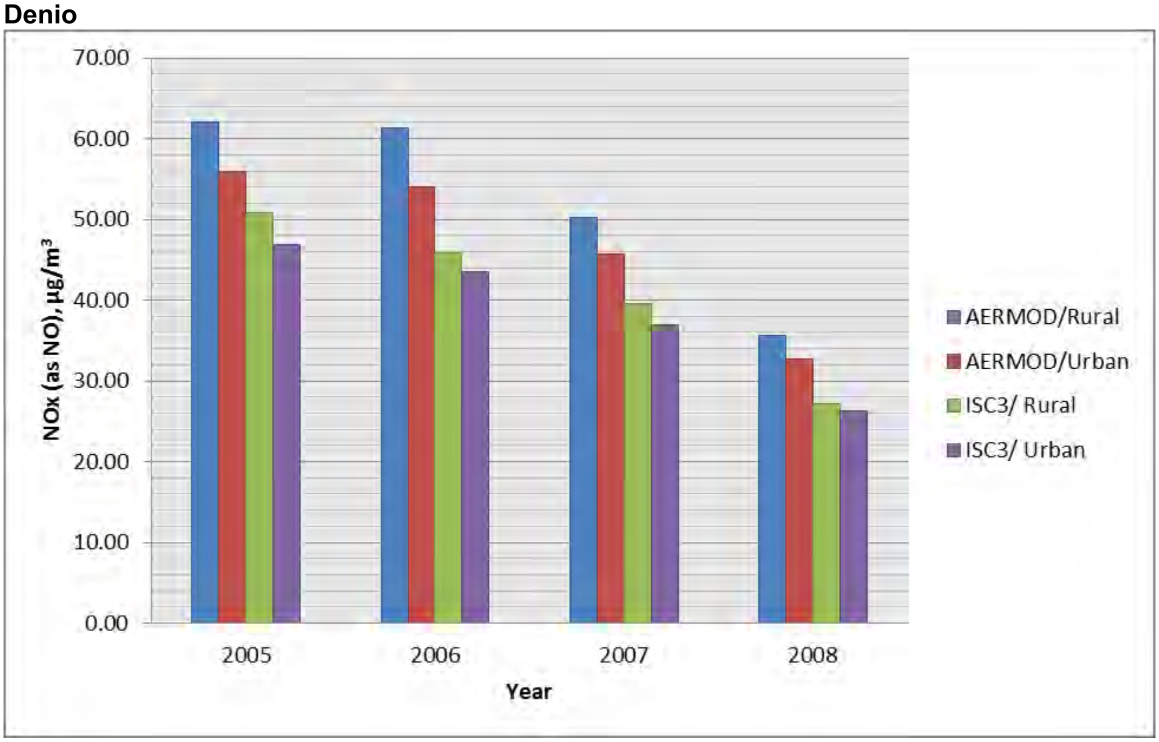


Figure 21 – Year to Year Trend, (DPM, annual average), Onsite Meteorological Data, Church

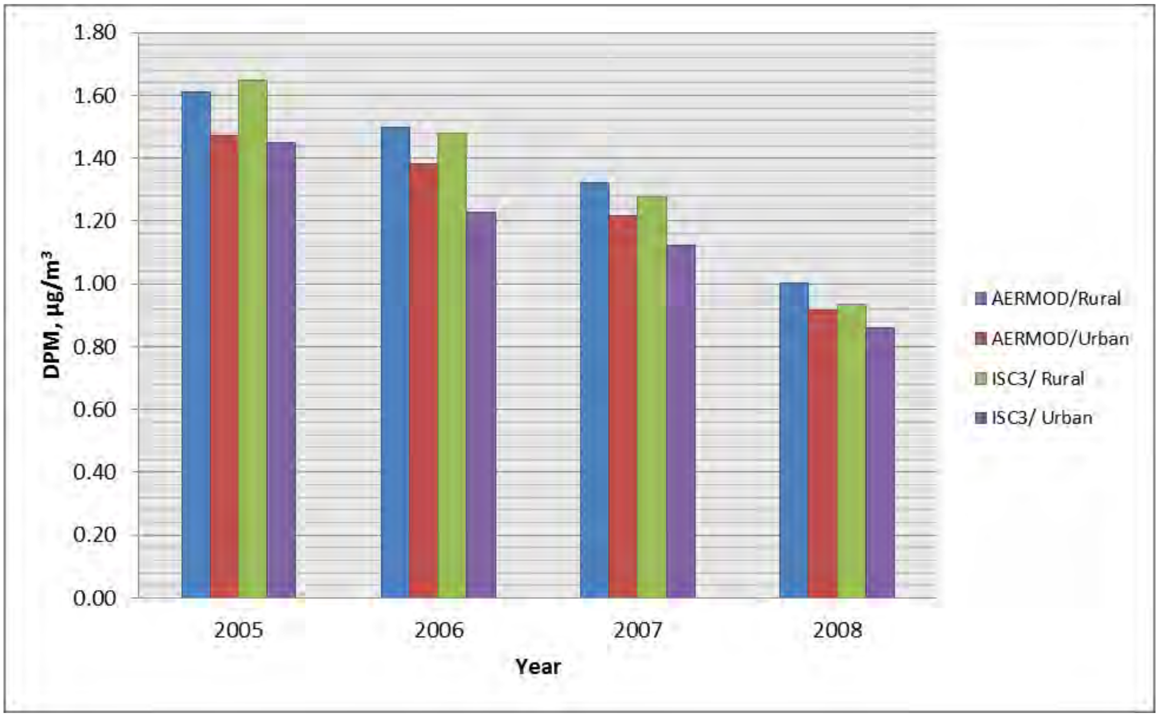


Figure 22 – Year to Year Trend, (NOx, as NO, annual average), Onsite Meteorological Data, Church

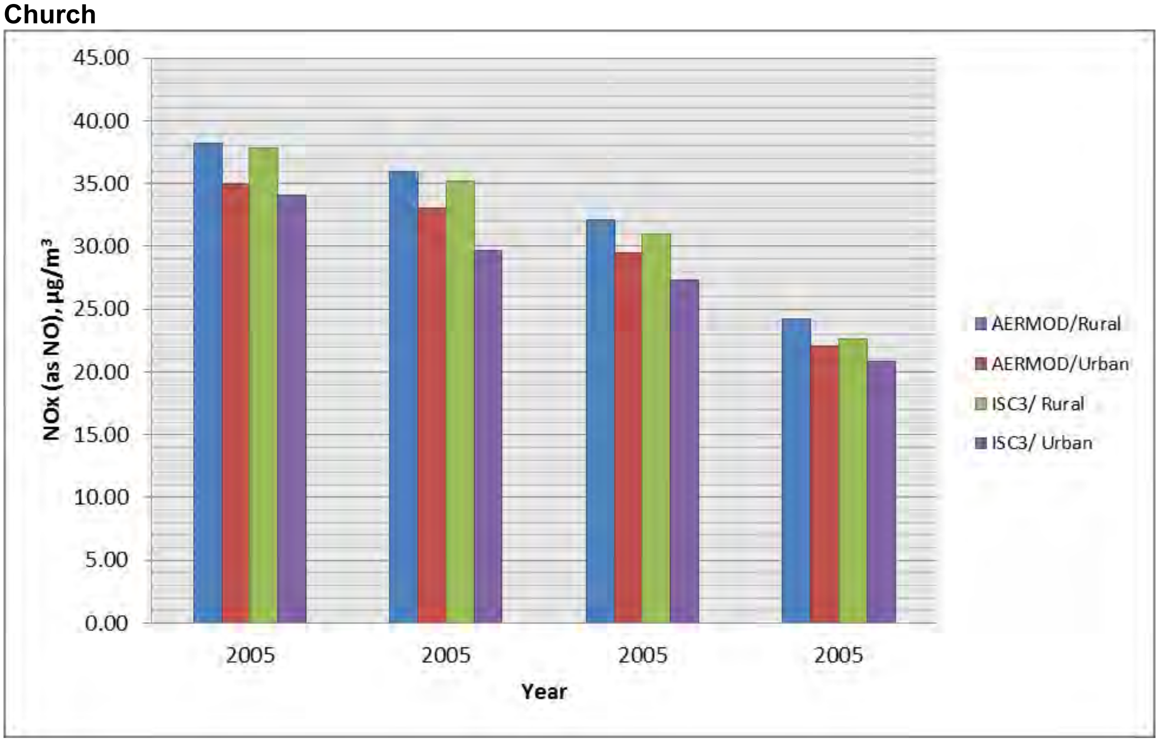


Table 3 – Comparison of model/mode predictions of RRAMP Season average nighttime NOx (as NO) concentrations (modeling based on onsite meteorological data)

	Basis	2005	2006	2007	2008
Denio site, RRAMP season average nighttime]concentration	AERMOD, Rural (µg/m^3)	80	81	64	49
	AERMOD, Urban (µg/m^3)	74	75	60	47
	ISCST, Rural (µg/m^3)	42	38	37	26
	ISCST, Urban (µg/m^3)	56	57	47	34
Church site, RRAMP season average nighttime concentration	AERMOD, Rural (µg/m^3)	44	38	35	26
	AERMOD, Urban (µg/m^3)	39	36	32	24
	ISCST, Rural (µg/m^3)	30	23	24	18
	ISCST, Urban (µg/m^3)	35	30	28	22

Table 4 – Comparison of model/mode predictions of RRAMP Season average nighttime DPM concentrations (modeling based on onsite meteorological data)

	Basis	2005	2006	2007	2008
Denio site, RRAMP season average nighttime concentration	AERMOD, Rural (µg/m^3)	3.73	3.69	2.77	2.13
	AERMOD, Urban (µg/m^3)	3.43	3.37	2.62	2.02
	ISCST, Rural (µg/m^3)	1.89	1.62	1.57	1.09
	ISCST, Urban (µg/m^3)	2.60	2.55	2.05	1.57
Church site, RRAMP season average nighttime concentration	AERMOD, Rural (µg/m^3)	2.05	1.67	1.51	1.11
	AERMOD, Urban (µg/m^3)	1.79	1.57	1.38	1.02
	ISCST, Rural (µg/m^3)	1.35	0.97	0.99	0.77
	ISCST, Urban (µg/m^3)	1.61	1.26	1.20	0.95

Another way of looking at the effect of choice of model on predicted impacts is to examine the area impacted by the facility, as shown in Figures 23 and 24. The isopleths show how the models differ in their prediction of the distribution of DPM and NOx (as NO) emitted from the rail yard. Figure 23 shows DPM isopleths, and Figure 24 shows NOx (as NO) isopleths, in the model/mode sequence of AERMOD RURAL, AERMOD URBAN, ISC RURAL, and ISC URBAN. These figures show that the lowest impacts, as represented by the extent of the area above a given concentration, are predicted by the two models using urban mode. Under most of the conditions in this study, AERMOD predicts higher concentrations than ISCST, when the same mode is used. Figures 23 and 24 show that ISCST (rural mode) predicts more complicated isopleths than the other three model/mode combinations. This appears to be the result of that model's higher sensitivity to the presence of a nearby source. Under certain conditions, the predicted concentrations at some points are more strongly affected by nearby sources than by others.

Figure 23 – Effect of Choice of Model/Mode, Predicted Annual Average DPM Isopleths (0.5 μg/m³), 2008, Onsite Meteorological Data

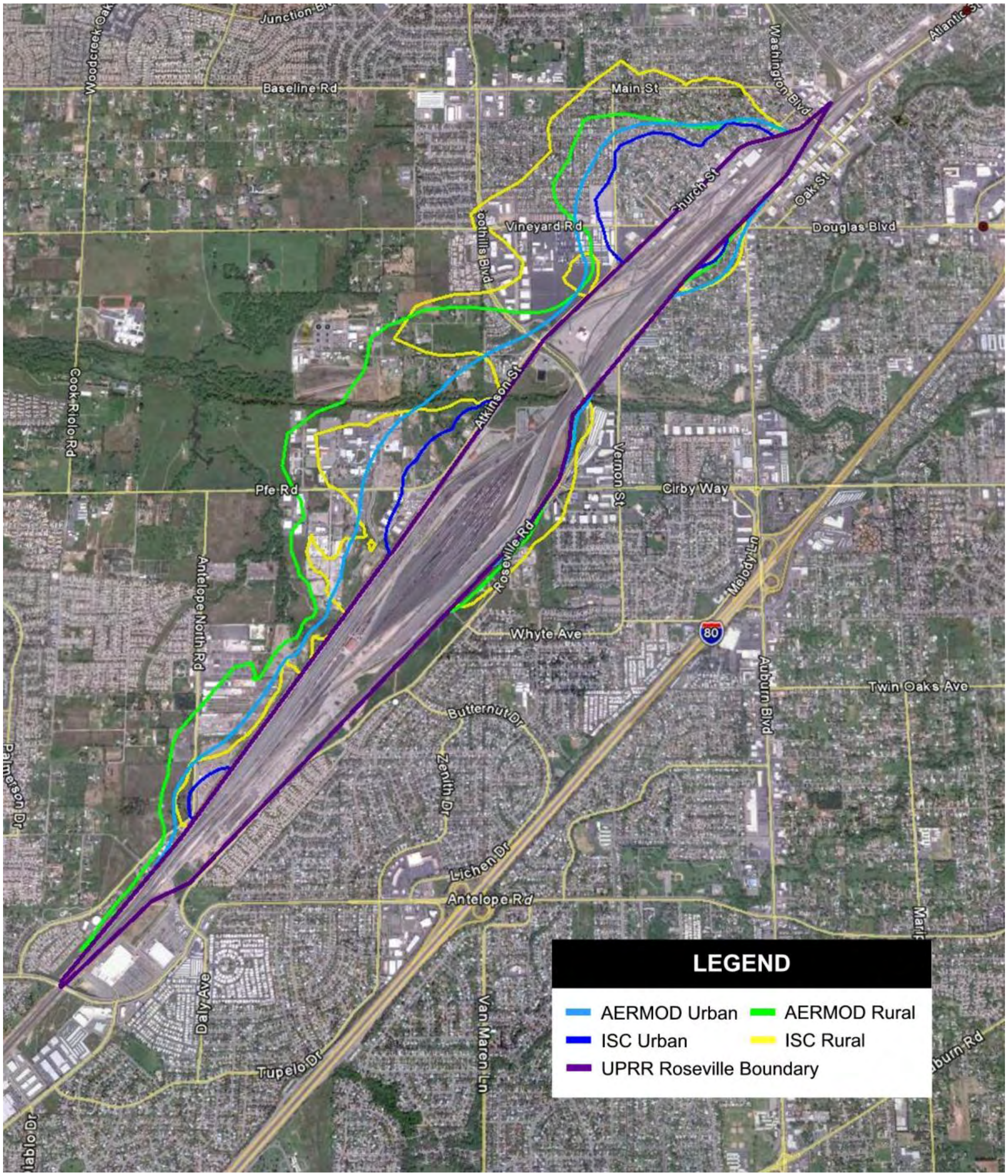
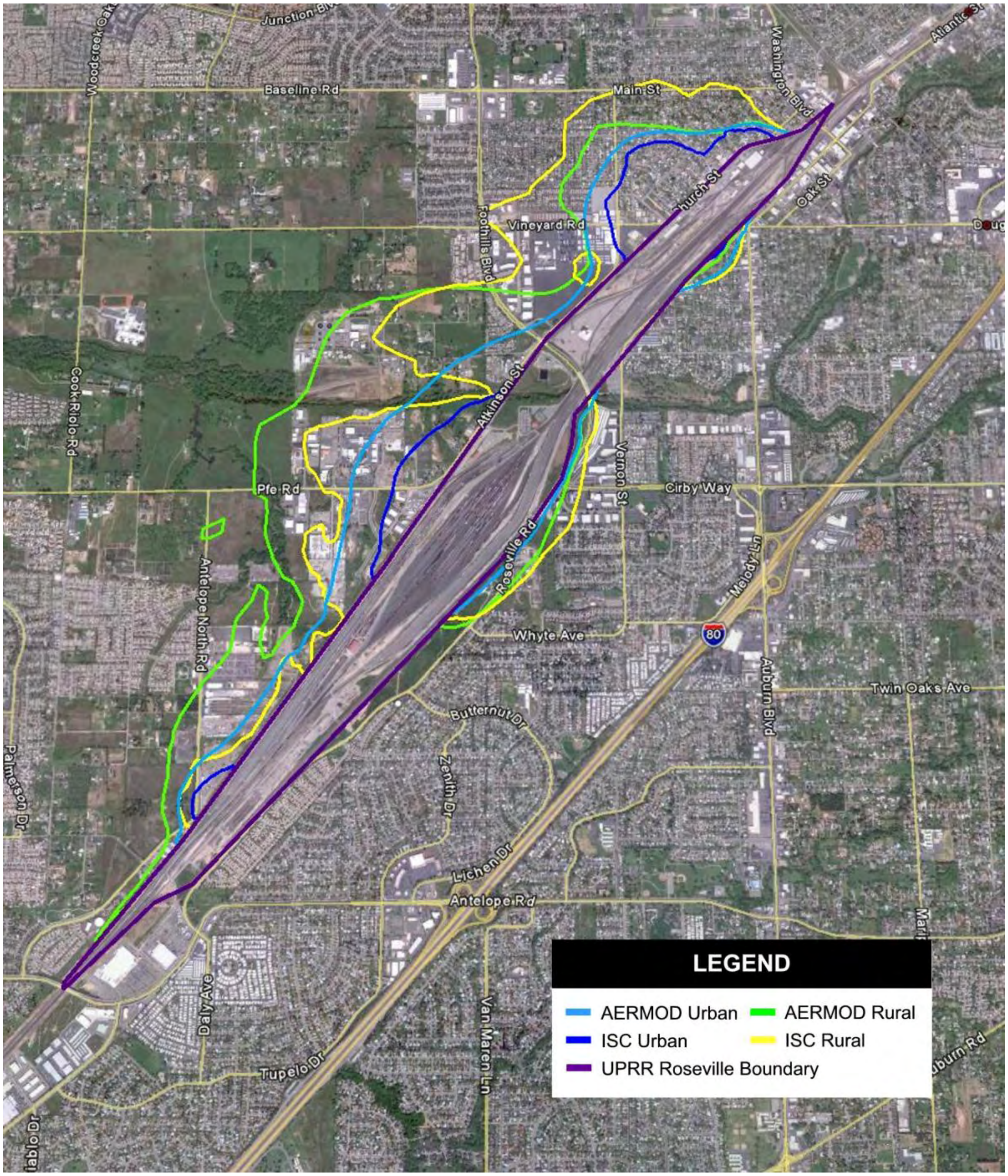


Figure 24 – Effect of Choice of Model/Mode, Predicted Annual Average NOx Isopleths (13 µg NO/m^3), 2008, Onsite Meteorological Data



This effect can be seen in Figures 20 and 22. Figure 20 shows the predicted annual average NOx (as NO) concentrations at Denio from 2005-2008, while Figure 22 shows the predicted NOx (as NO) concentrations at Church. Figure 22 shows that the predictions at Church reflect the general trend (predicted concentrations from both models using urban mode are lower than predicted concentrations from both models using rural mode); however, Figure 20 shows that at some locations, rural mode ISCST predicts lower concentrations than urban mode AERMOD.

It can be generally said that, given the same model, rural mode results in higher predicted impacts (demonstrating the importance of accurate characterization of the land use); also, given the same dispersion mode, AERMOD tends to predict higher impacts.

Location of Monitoring Sites – Early modeling indicated that there might be steep concentration gradients at some locations, due to location of sources, building downwash effects, and other factors. For a monitor site that is located in an area with a steep concentration gradient, a small difference in location could have a large effect on the predicted concentration. This would make it much more unlikely that a correlation between predicted concentrations and monitoring data could be found.

To assess the sensitivity of the modeling results to the precise location of the monitoring sites, the predicted concentrations at the receptors surrounding the monitoring sites were compared. These comparisons were made for DPM and NOx (as NO) annual average concentrations for a single year (2005) for each of the four model/modes, using onsite data. Figures 25 through 28 show variations within 20 meters of the monitoring sites using a 10 meter grid. The layout of the fine grid of receptors around each monitoring site is shown in Figure 29. Figures 30 through 33 show variations within 200 meters of the monitoring sites using a 50 meter grid.

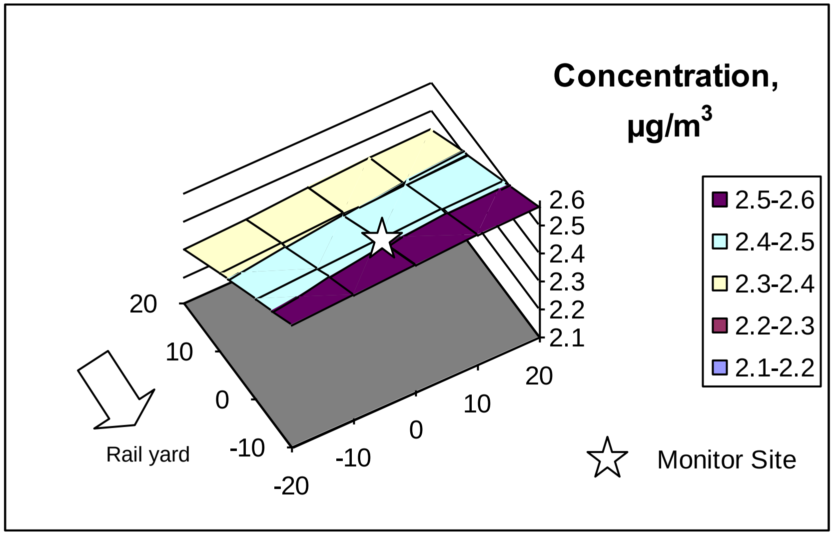
Figures 25 and 26 show that, in the immediate vicinity of the Denio monitor, the models predict a distinct increase in annual average emissions as the receptor moves toward the rail yard (about 14% increase in concentration over 30 meters). Moving the monitor 20 meters to either side has little effect on predicted concentration.

Figures 27 and 28 show greater variability around the Church monitor, both towards the rail yard and parallel to the rail yard property line. The highest prediction is 75% higher than the lowest prediction in this 30 by 40 meter grid (i.e., 1.95/1.12 using ISCST3 Urban), and is likely influenced by the proximity of this monitoring site to the shop.

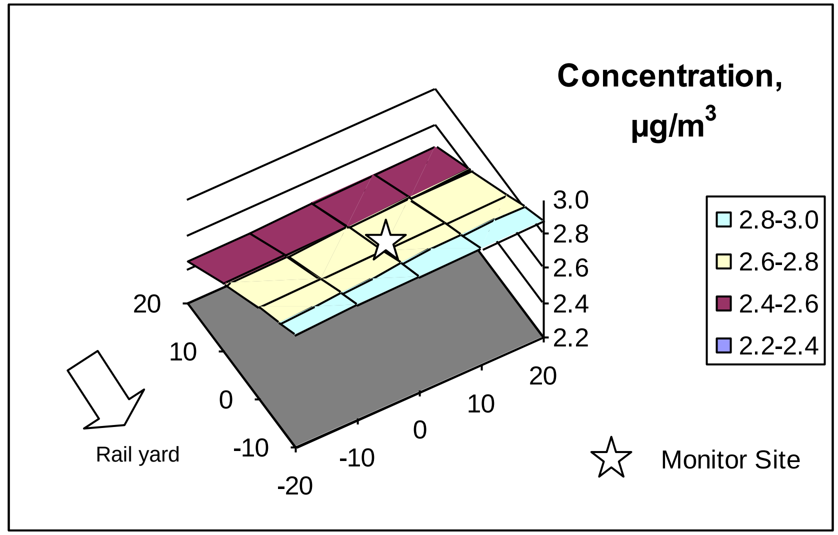
Figures 30 through 33 show a higher degree of variability as a larger area is considered. For example, the models predict two high concentration peaks within 100 meters of the Church monitor (see Figures 32 and 33). The highest predicted concentration within 100 meters of the Church monitor is more than 3.8 (i.e., 3.8/1.0=3.8) times the prediction at the monitor.

Figure 25 – Predicted concentrations near the Denio monitor. Annual Average DPM, 2005 (10 meter grid spacing)

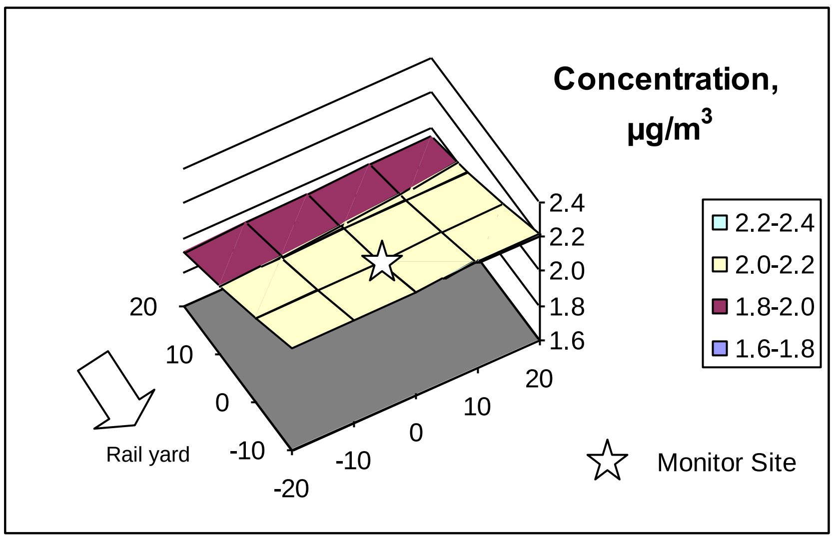
AERMOD Urban



AERMOD Rural



ISC Urban



ISC Rural

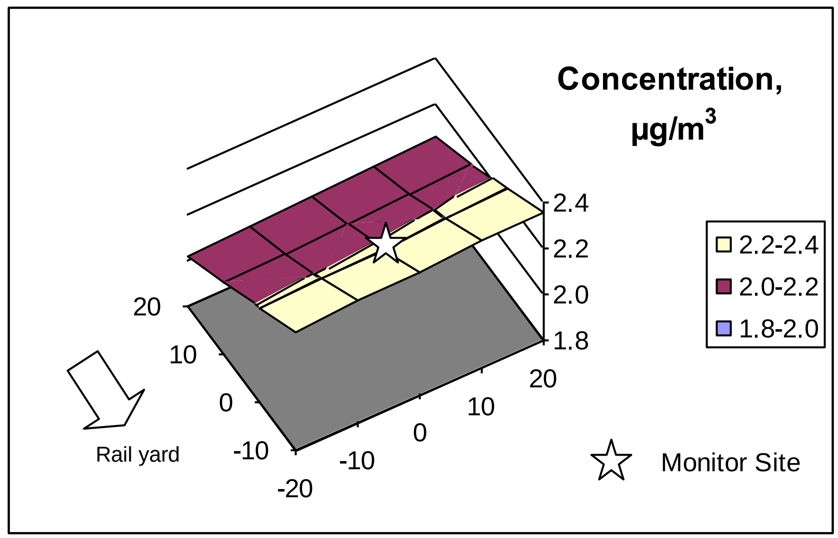
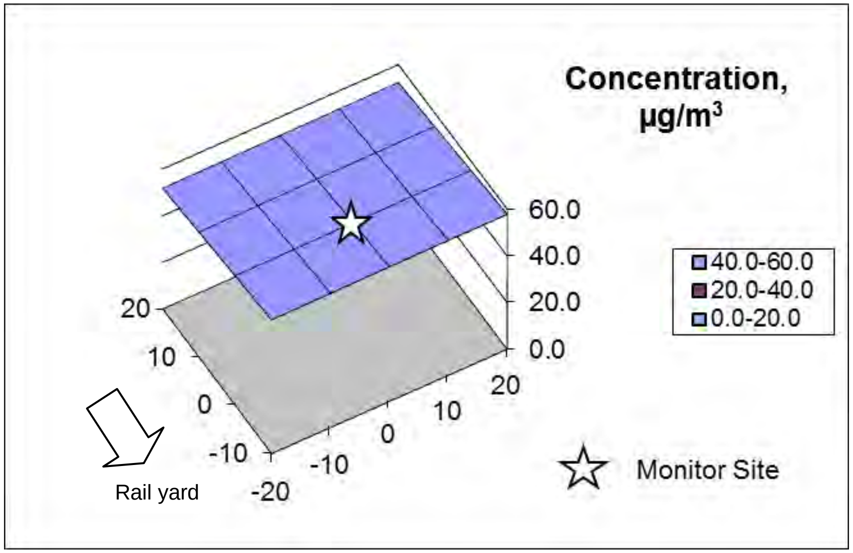
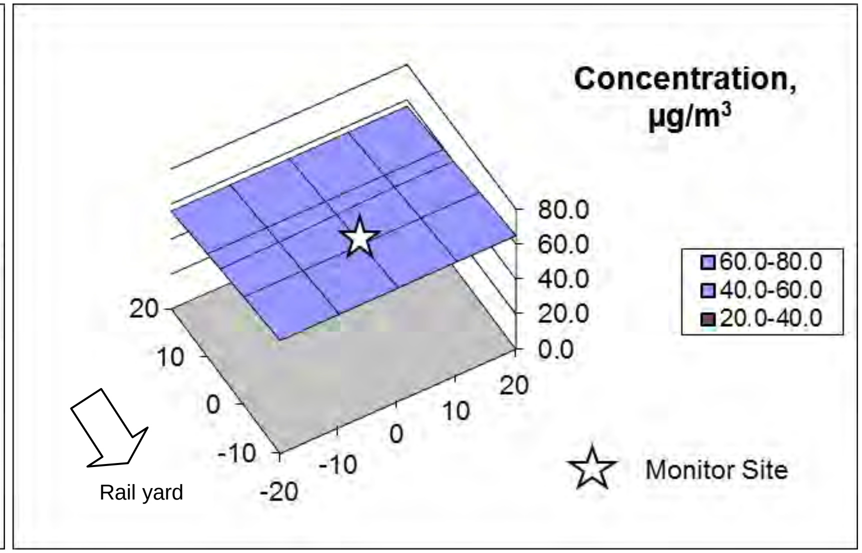


Figure 26 – Predicted concentrations near the Denio monitor. Annual Average NOx (as NO), 2005 (10 meter grid spacing)

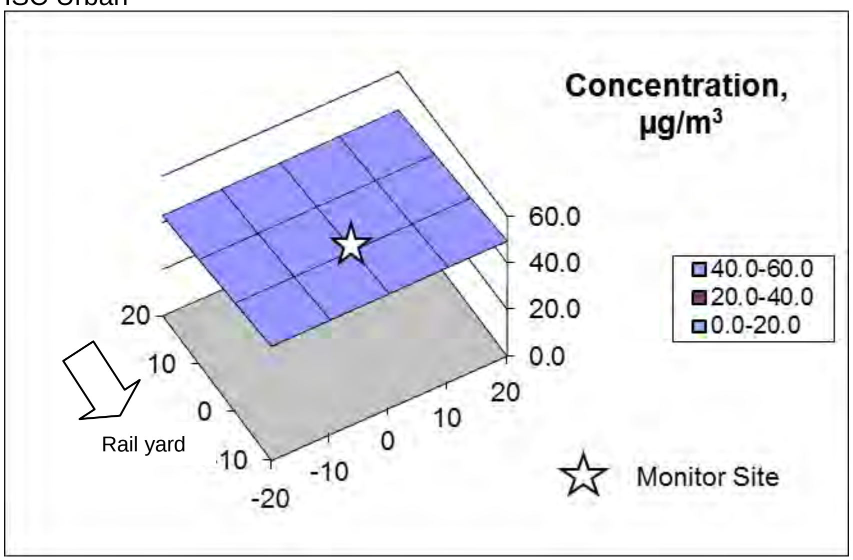
AERMOD Urban



AERMOD Rural



ISC Urban



ISC Rural

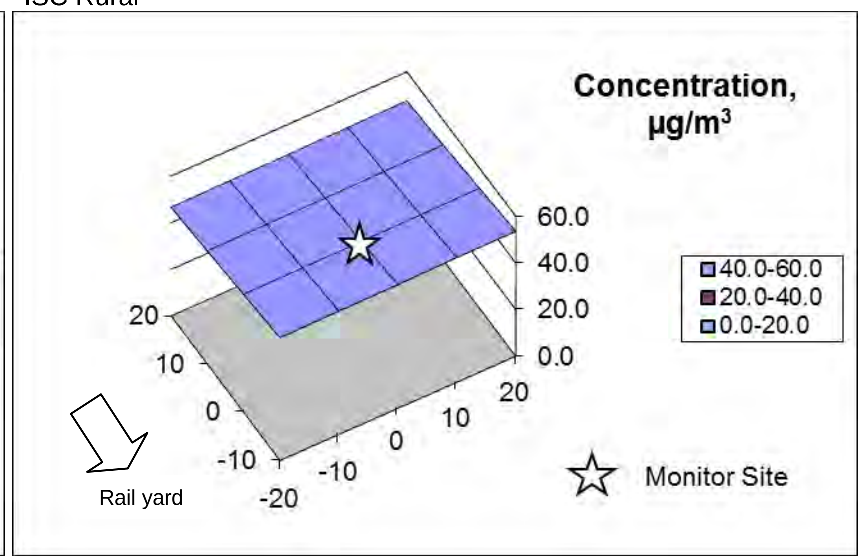
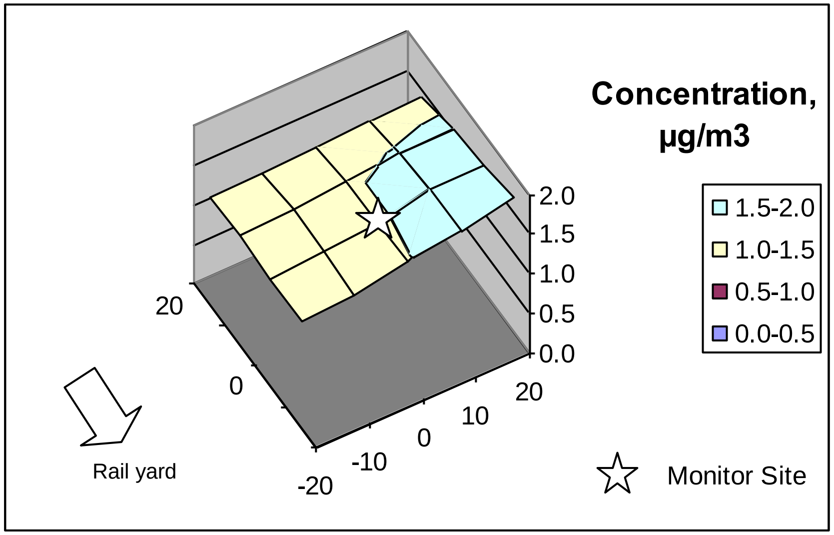
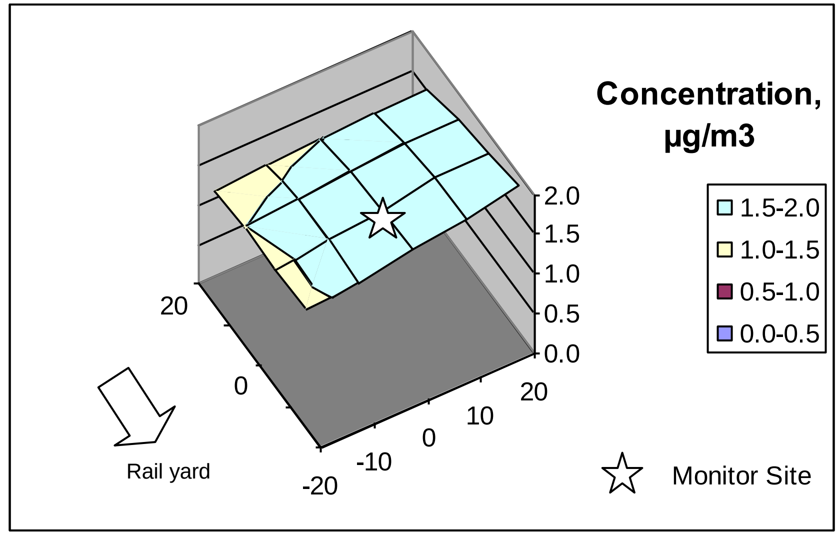


Figure 27 – Predicted concentrations near the Church monitor. Annual Average DPM, 2005 (10 meter grid spacing)

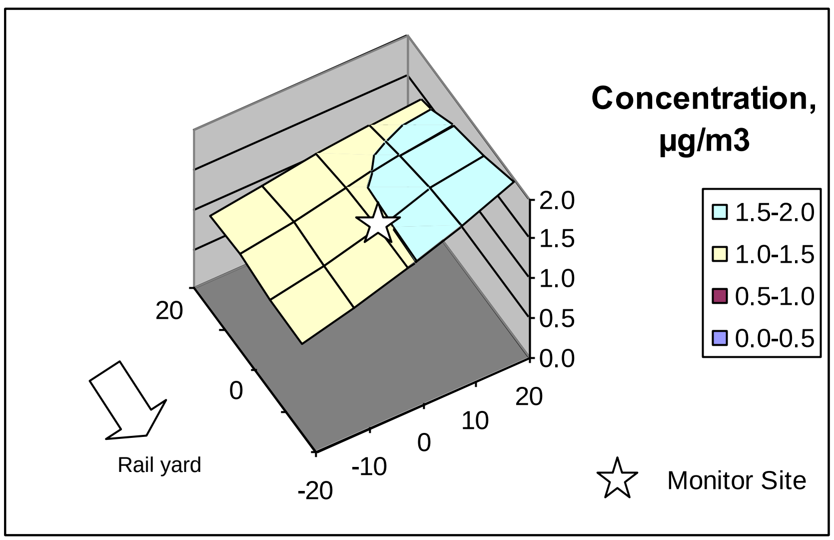
AERMOD Urban



AERMOD Rural



ISC Urban



ISC Rural

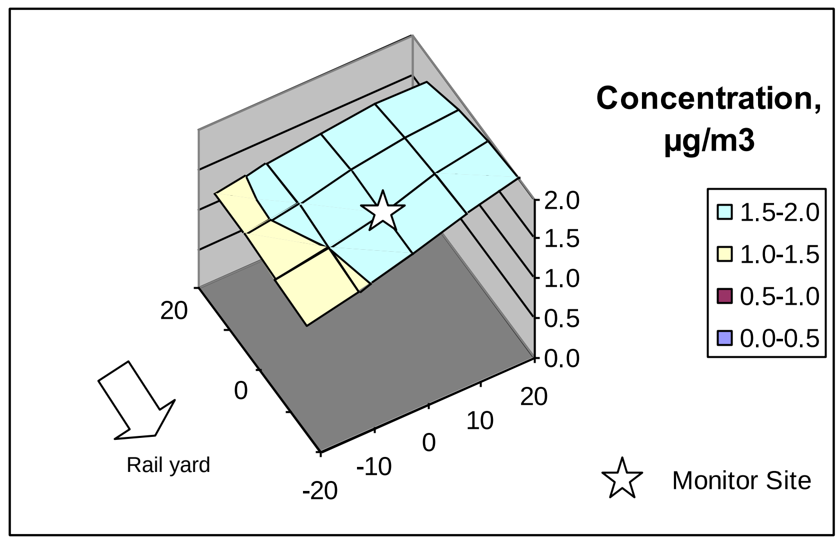
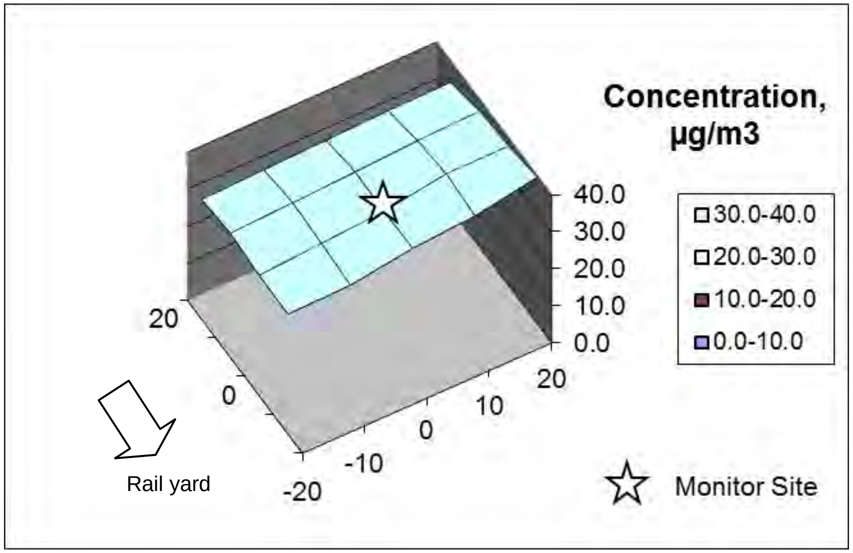
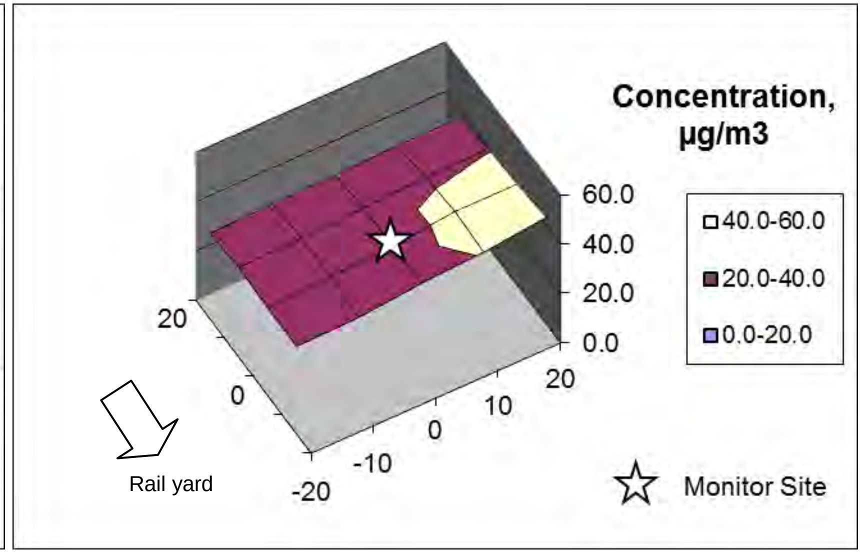


Figure 28 – Predicted concentrations near the Church monitor. Annual Average NOx (as NO), 2005 (10 meter grid spacing)

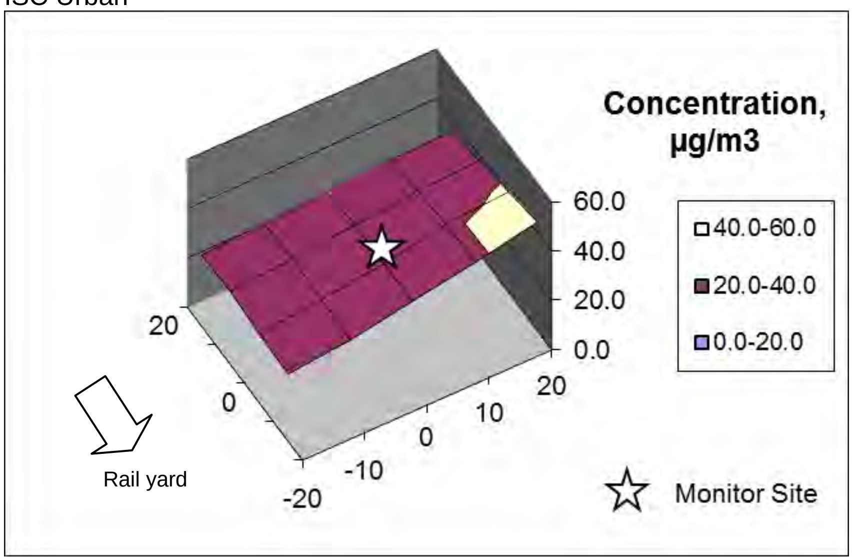
AERMOD Urban



AERMOD Rural



ISC Urban



ISC Rural

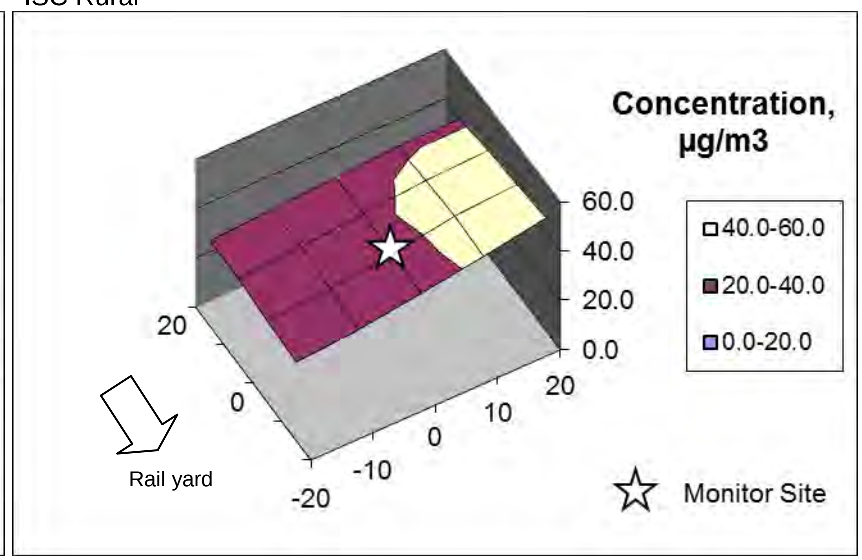


Figure 29 – Fine Grid (10 m) 20 Receptor Position-Sensitivity Testing Arrangement Surrounding RRAMP Monitoring Sites

20	20	20	20	20	Fourth row of receptors around Denio or Church
20	9	9	9	20	
20	9	**R**	9	20	**R** represents the Denio or Church monitoring site
20	9	9	9	20	First row of receptors nearest the rail yard

20	9	9	9	20	First row of receptors nearest the rail yard
20	9	**R**	9	20	**R** represents the Pool or Vernon monitoring site
20	9	9	9	20	
20	20	20	20	20	Fourth row of receptors around Pool or Vernon

Note -The 9-receptor cluster around Site R is shown as the cells marked 9 and **R**. The 20-receptor cluster around Site R is shown as the cells marked 9, 20 and **R**.

Figure 30 – Predicted concentrations near the Denio monitor. Annual Average DPM, 2005 (50 meter grid spacing)

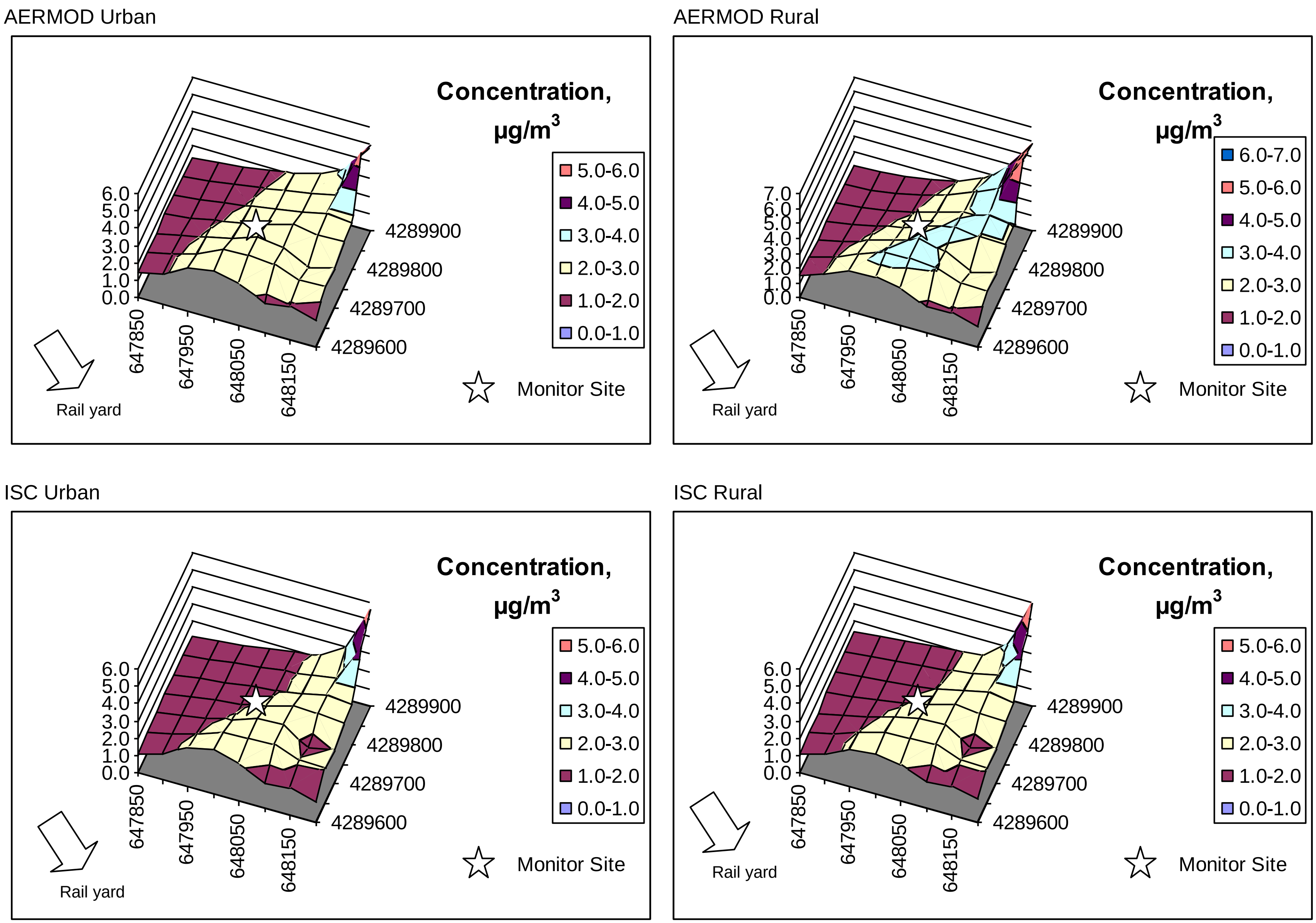
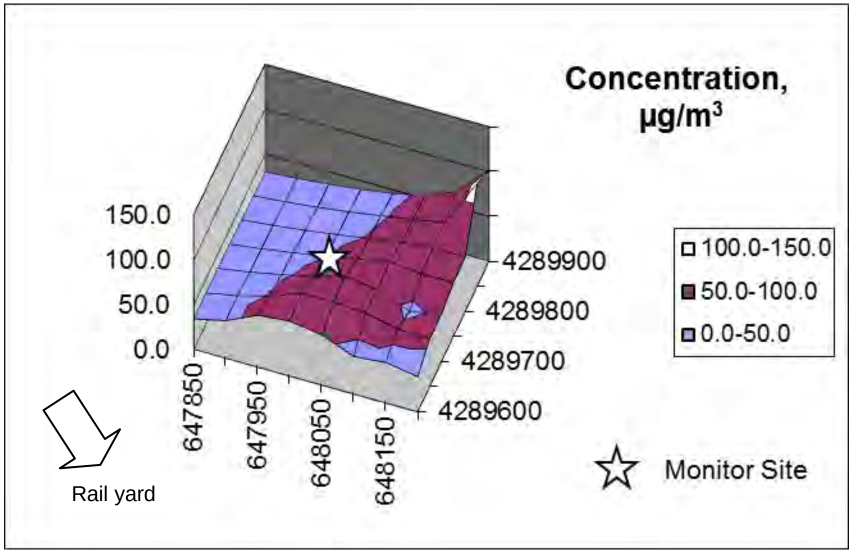
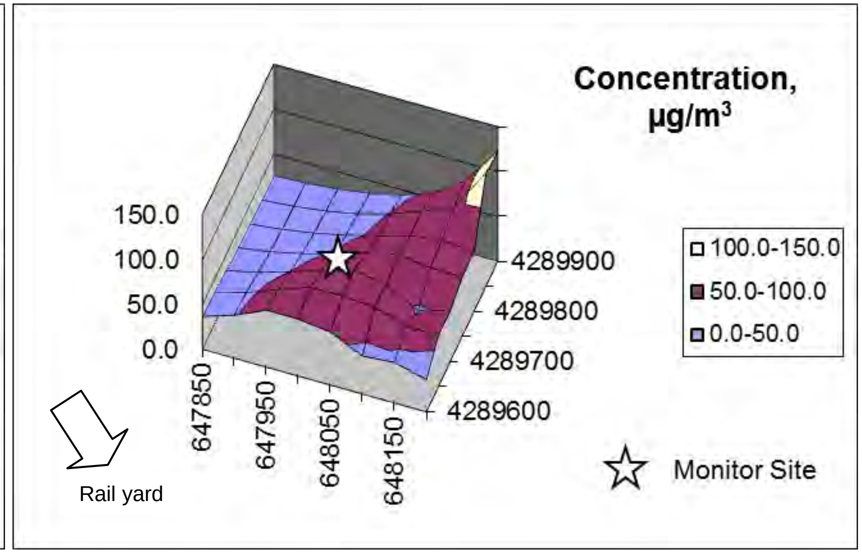


Figure 31 – Predicted concentrations near the Denio monitor. Annual Average NOx (as NO), 2005 (50 meter grid spacing)

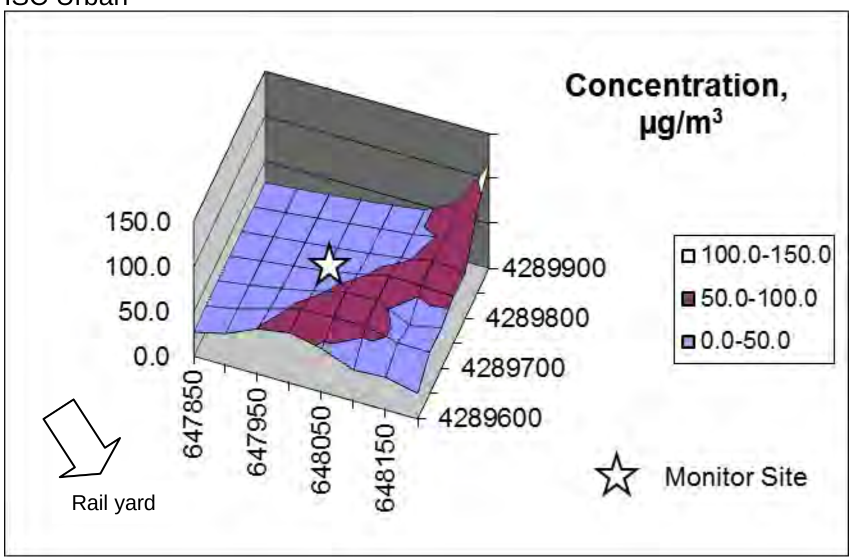
AERMOD Urban



AERMOD Rural



ISC Urban



ISC Rural

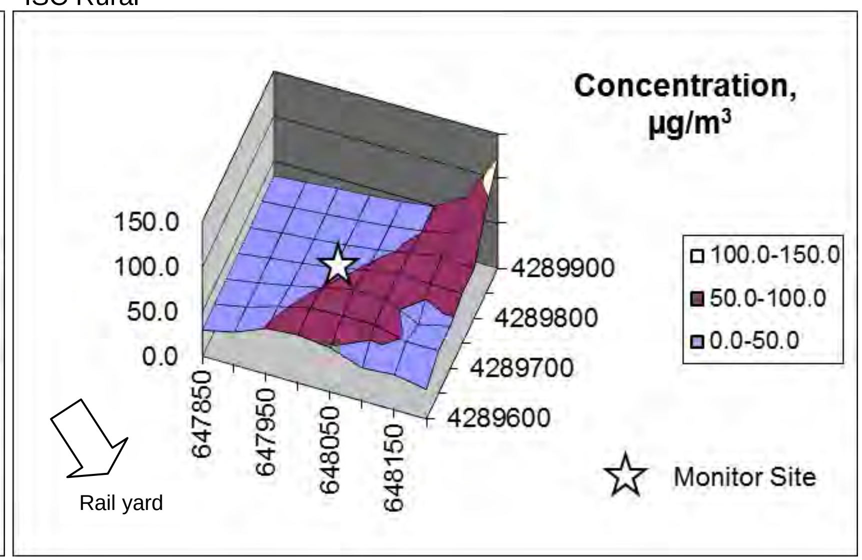


Figure 32 – Predicted concentrations near the Church monitor. Annual Average DPM, 2005 (50 meter grid spacing)

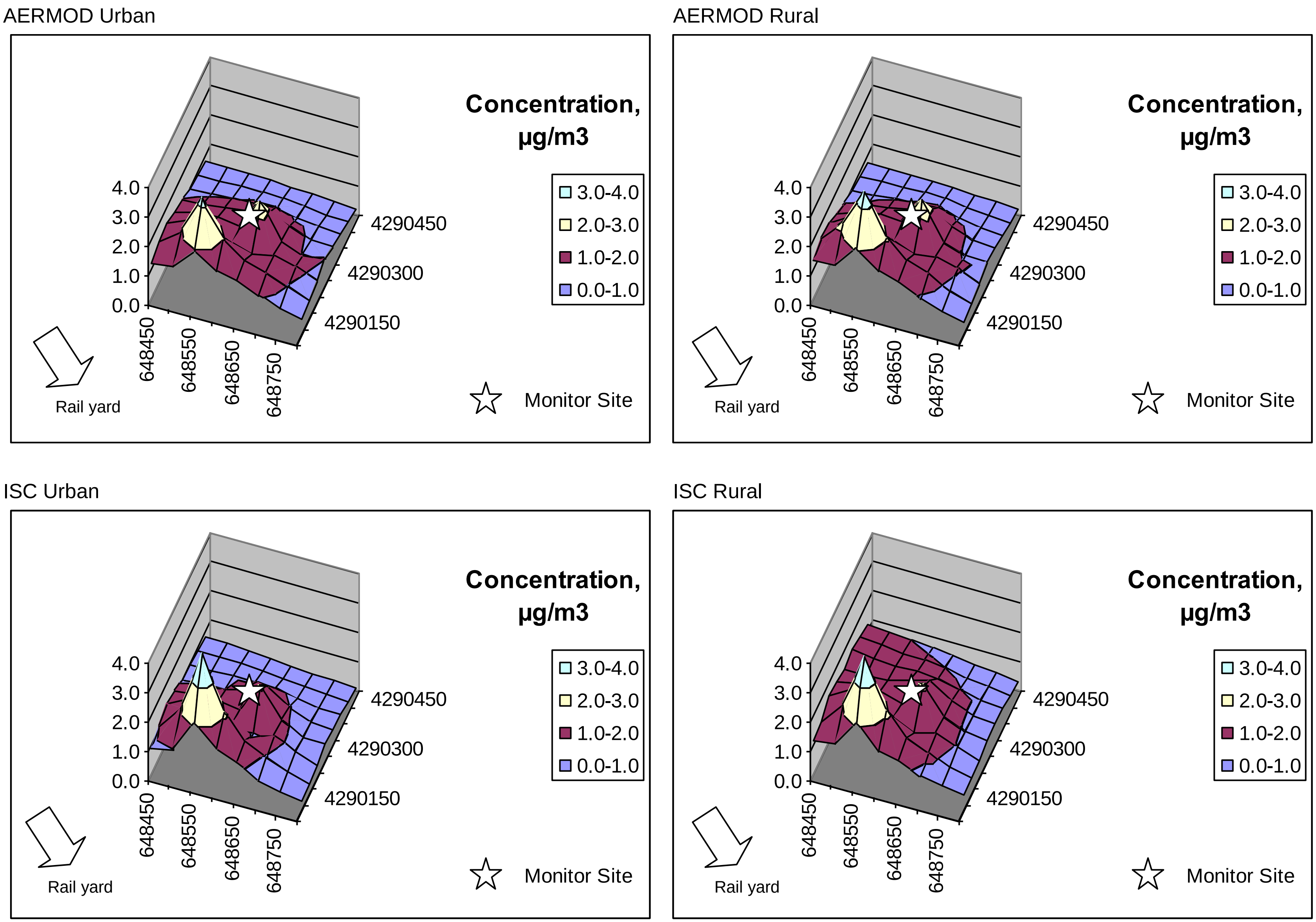
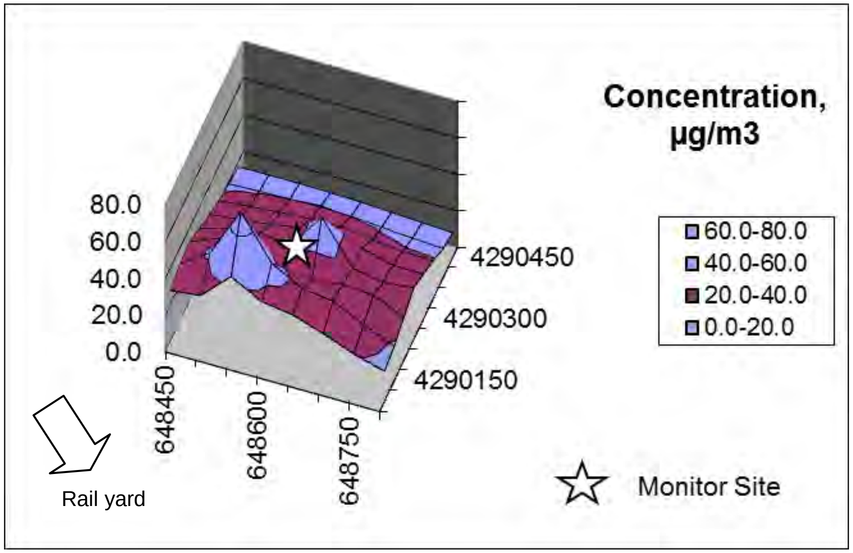
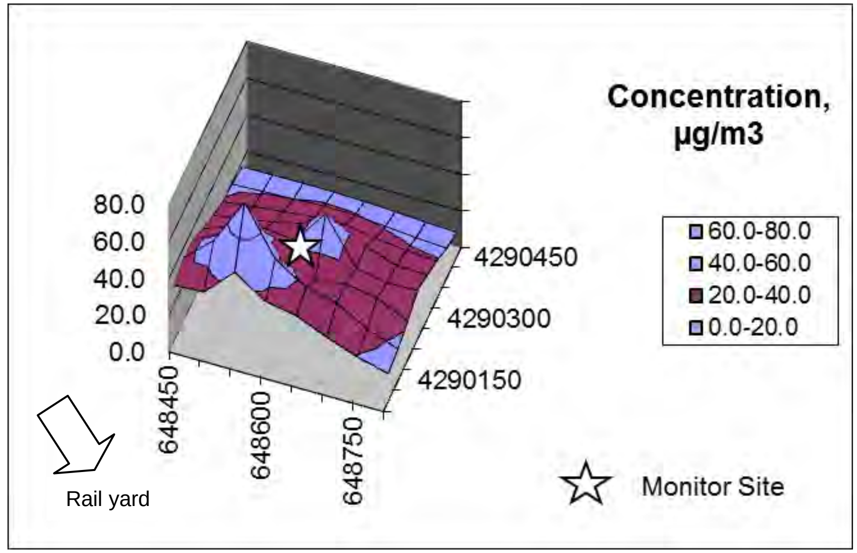


Figure 33 – Predicted concentrations near the Church monitor. Annual Average NOx (as NO), 2005 (50 meter grid spacing)

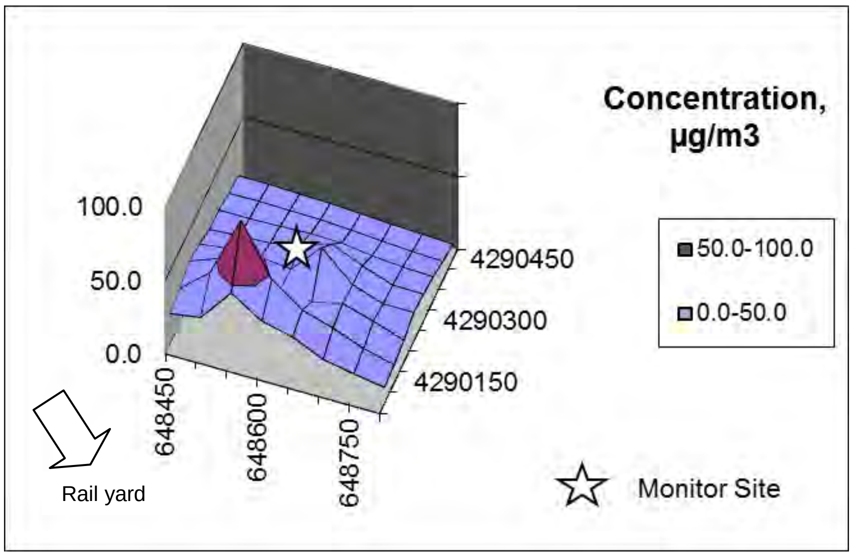
AERMOD Urban



AERMOD Rural



ISC Urban



ISC Rural

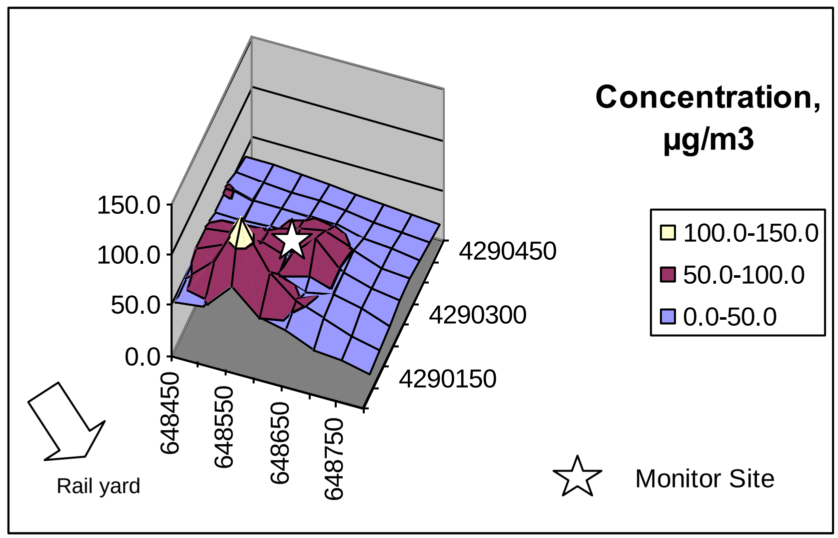
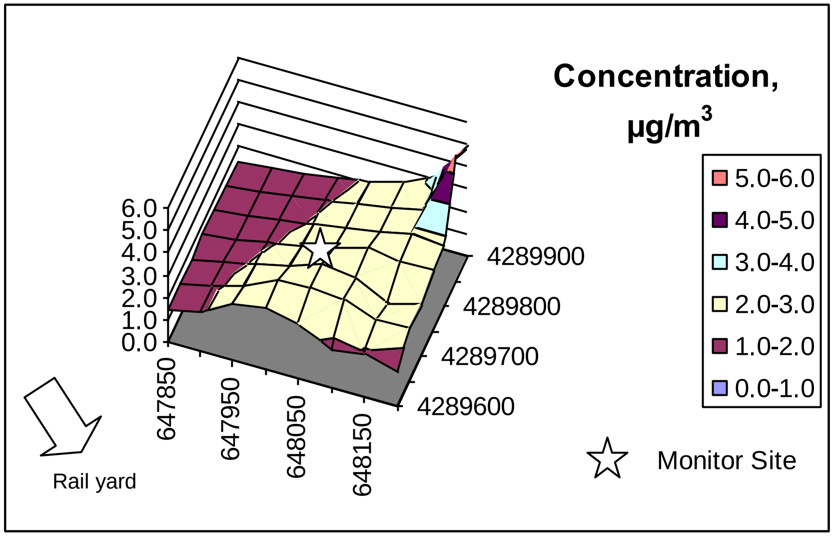
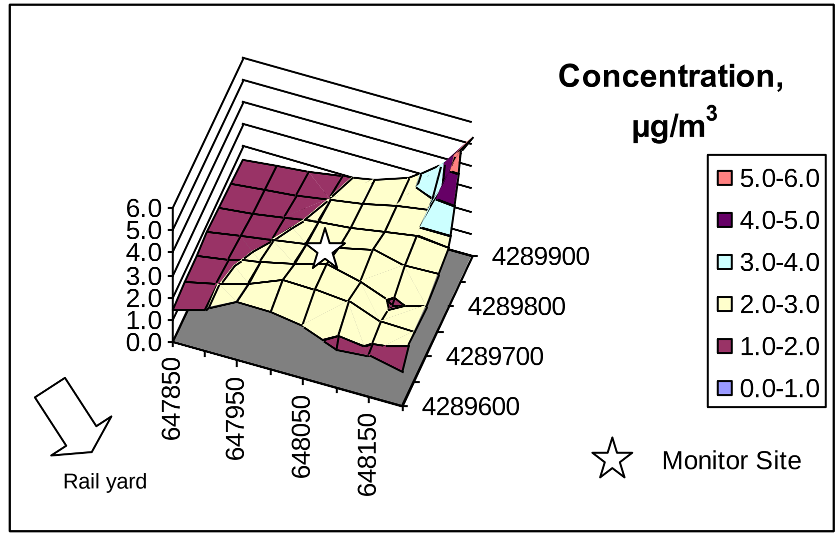


Figure 34 – Predicted concentrations near the Denio Monitor. Annual Average DPM, 2005; AERMOD, Urban; Onsite vs. Roseville Meteorological Data

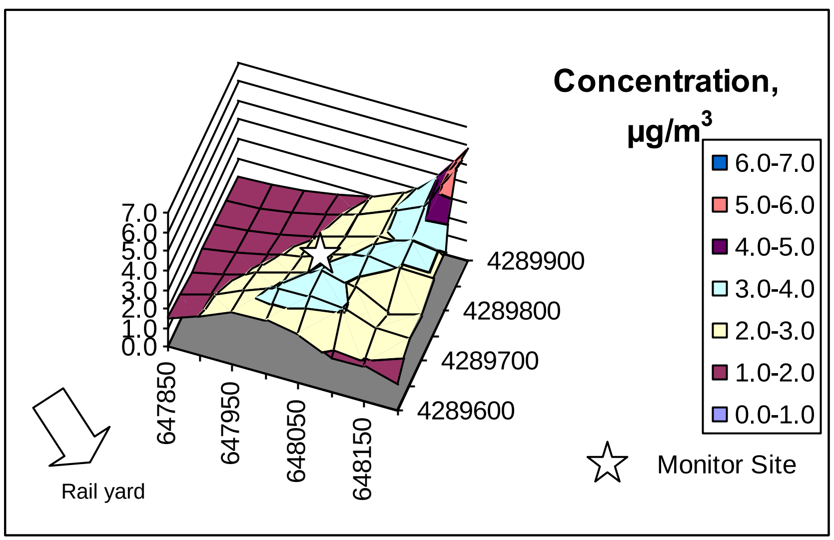
AERMOD Urban, onsite meteorological data



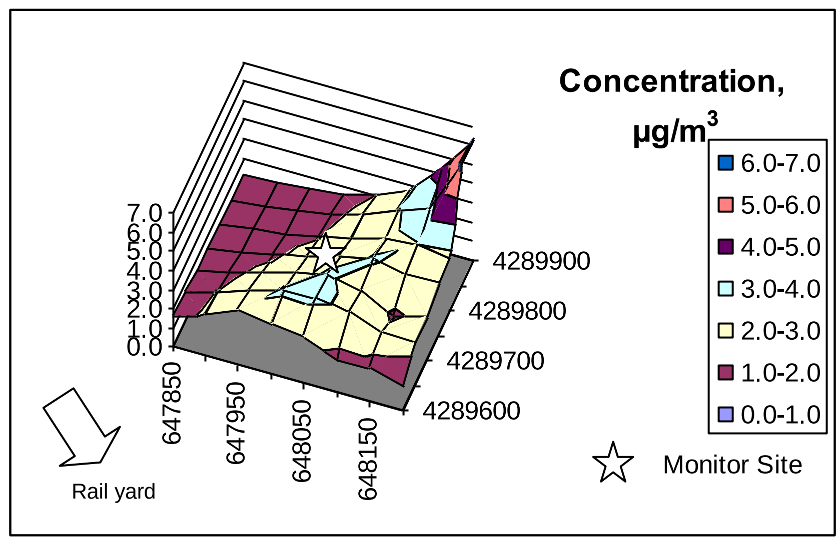
AERMOD Urban, Roseville meteorological data



AERMOD Rural, onsite meteorological data



AERMOD Rural, Roseville meteorological data



This variability means that a relatively small mischaracterization of one or more sources at the rail yard (either location or magnitude of emissions) could move the impact peak toward or away from the monitor site, thus making a significant change to the predicted concentration at the monitor. The nature of many sources at the rail yard (e.g., moving vehicles represented as area sources) means that it is likely that either the strength or location of these sources is not accurate.

Additionally, this variability means that differences in the meteorological data, which appear to be small when comparing overall impacts, can have a significant impact on the concentration predicted for a specific receptor. For example, examination of Figures 7 through 10 shows that the prevailing winds in the Roseville data are more easterly by approximately 22.5° than those in the onsite data.

Figures 11 through 18 show that this difference in wind direction has little effect on overall facility impacts; this difference also has little effect on impacts at the monitors (see Figure 33 for the Church monitor example). This might indicate that the annual average concentrations, both generally and at the monitors, are dominated by low wind speed conditions. Figure 34 shows that the magnitude of the variability does not depend on the choice of meteorological monitoring station, using as an example AERMOD's predictions of DPM concentrations around the Denio monitoring site, and with the model run in both Urban and Rural modes. The similarity previously noted between the two meteorological monitoring station data sets results in similar predictions of impacts.

In summary, both downwind monitoring sites are located in an area where the predicted concentrations vary greatly over a distance as small as 50 meters.

5.2 Change in Emissions Over Time

As discussed above, emissions from the facility were reduced each year during the RRAMP study period. In addition, some activities were moved from one location at the facility to another, or dispersed more widely throughout the rail yard. It is interesting to note the effect that these changes had on predicted dispersion of pollutants. Figure 35 illustrates how the area impacted by the facility (as represented by 0.5 $\mu g/m^3$ DPM isopleths) has shrunk over the four years of the RRAMP study. Figure 36 illustrates how the NOx impacts (as represented by 13 μg NO/m^3 isopleths) have decreased over the same time. Figures 15-18 show the decline in predicted DPM concentrations in the vicinity of the rail yard from 2005 to 2008.

Figure 35 – Area of Impact Over Time, 4 Years (2005~2008) Predicted Annual Average DPM Isopleths (0.5 μg/m^3), AERMOD, Urban Mode, Onsite Meteorological Data

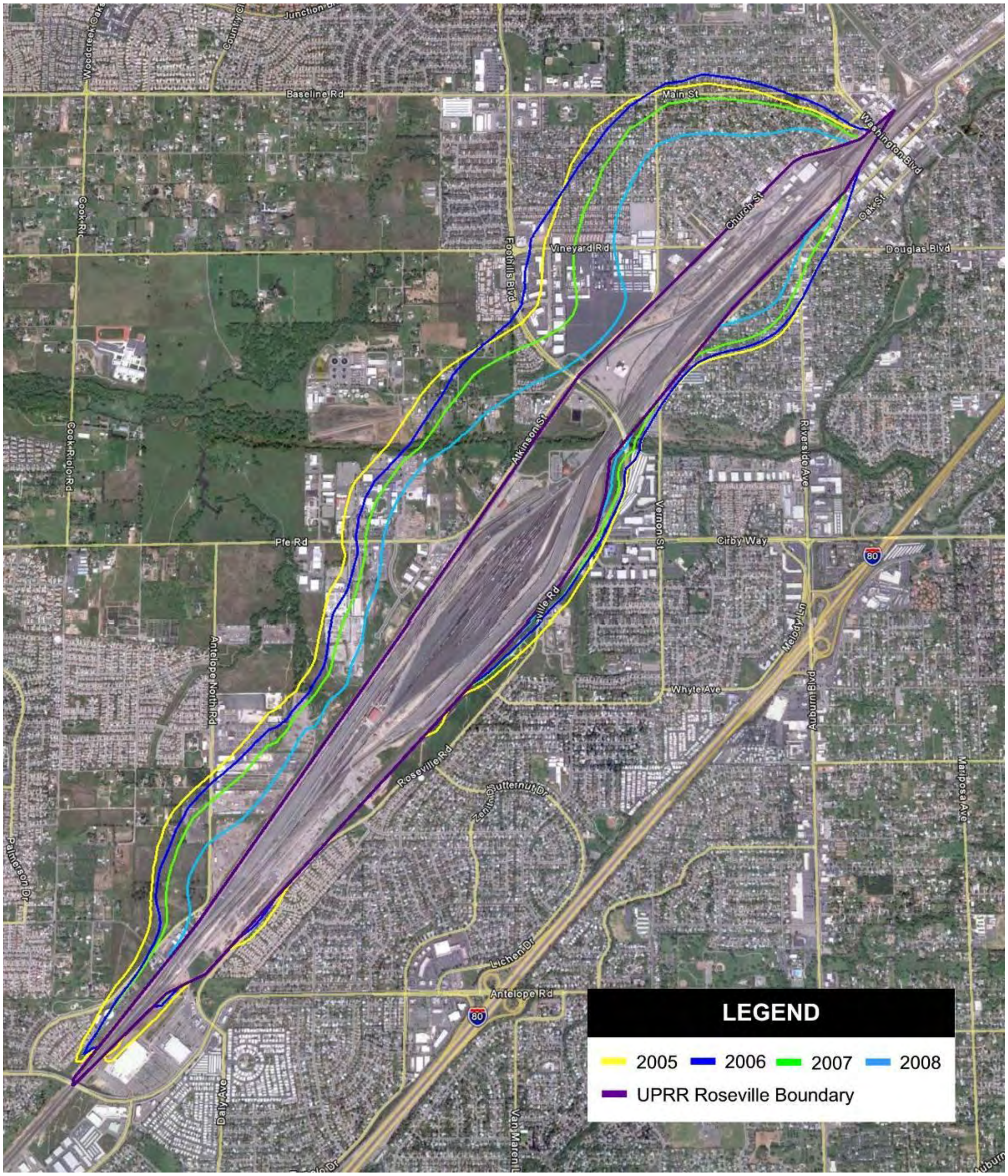
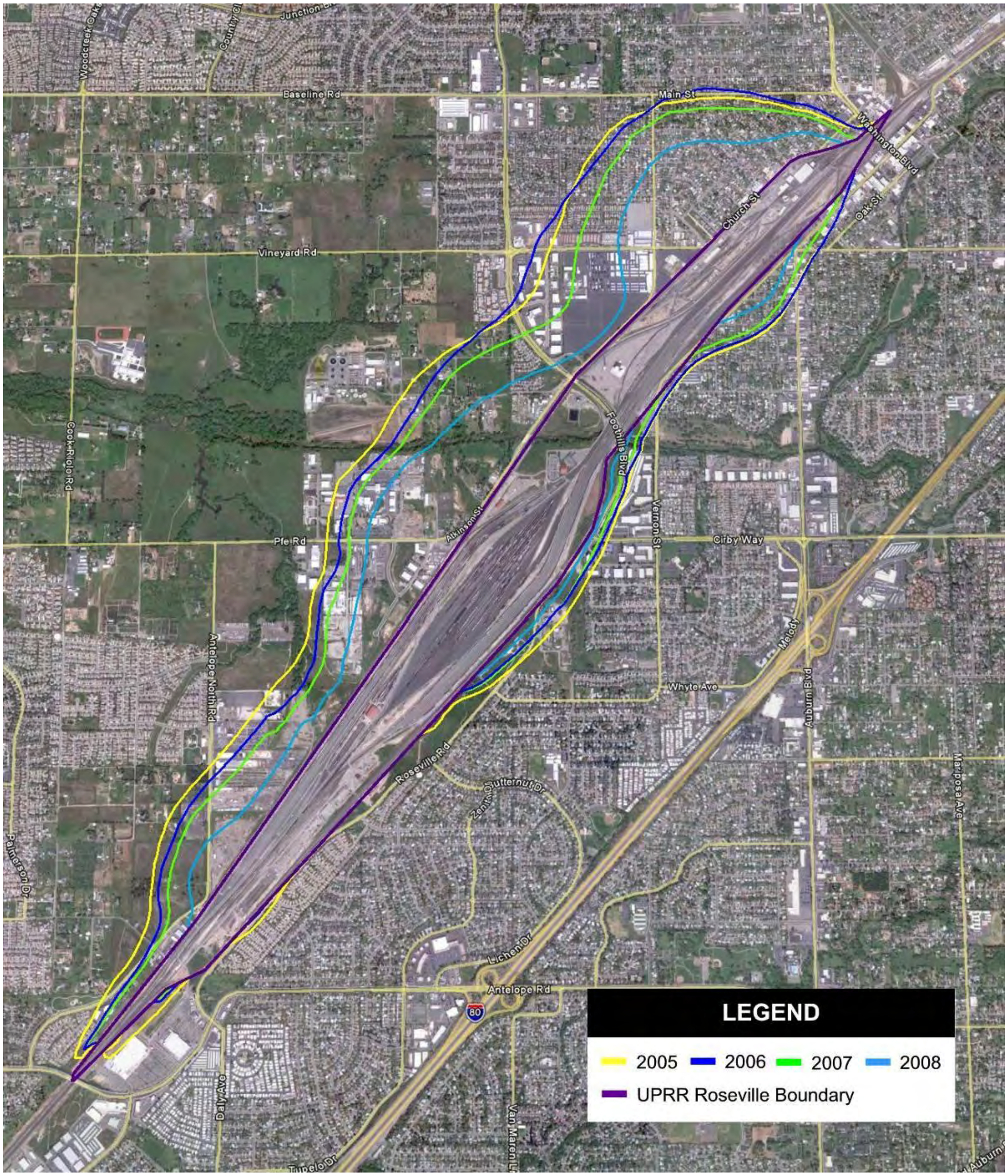


Figure 36 – Area of Impact Over Time, 4 Years (2005~2008) Predicted Annual Average NOx Isopleths (13 µg NO/m^3), AERMOD, Urban Mode, 2005 Annual Average Emissions, Onsite Meteorological Data



5.3 Comparison of Modeled with Monitored Concentrations

Comparison of modeled with monitored concentrations of a pollutant that was both modeled and measured provides a basis for discussing the accuracy and bias of the dispersion models. (Note: As discussed above, the regulatory purpose for which the models were developed means that the models were intended to result in a conservative [high] prediction in most cases.) Considerations that complicate the analysis include how well the “upwind/downwind” monitoring sites are located; how well the sources were characterized in modeling terms; and whether other sources, both onsite and offsite, might interfere with the results.

Comparison of Modeled and Monitored NOx (as NO) Concentrations – Table 5 contains the summary data for comparison of modeled NOx (as NO) concentrations based on the AERMOD dispersion model (Urban Mode)[28] with monitored NOx (as NO) data for the Denio site, and Table 6 contains the same parameters for the Church site. In these tables, the RRAMP season average concentrations for the nighttime hours (10 PM to 5 AM PST) when the wind was blowing from the southeast quadrant are compared. The concentrations are also charted in Figures 37 and 38. The monitoring data presented in the tables and figures are the differences between the downwind and upwind measurements, in an attempt to measure the impact from the rail yard at the monitoring site.

[28] ISCST3 and AERMOD, EPA’s preferred model replacement for ISCST3, provide special treatment for nighttime dispersion in urban settings. Both models enhance the calculated nighttime turbulence in stable conditions. ISCST3’s basic dispersion algorithm is a steady-state Gaussian formulation that calculates both lateral and vertical dispersion coefficients based on simple atmospheric stability class calculations. Stability classes range from A (very unstable) to F (very stable). In urban settings, mechanical turbulence induced by buildings and surface heating from human activities prevent truly stable conditions at night. Therefore, if URBAN dispersion is specified for ISCST3 simulations, hours that would normally be classified as “stable” (E) or “very stable” (F) are modeled as if they were “neutral” (D). AERMOD uses a much more complex algorithm to calculate dispersion coefficients, which includes treatment of solar insolation, surface albedo (brightness/reflectivity), surface moisture, and surface roughness. If the URBANOPT dispersion option is specified, additional calculations are carried out which account for buildings in urban areas that trap outgoing thermal radiation, and enhance the turbulence above that found in the rural stable boundary layer. This AERMOD URBANOPT calculation is based on an empirical model from temperature difference data for a number of Canadian cities with different populations.

Table 5 – Comparison of Modeled and Monitored NOx (as NO) RRAMP Season Period-Average Nighttime Concentrations at the Denio Monitoring Site, Onsite Meteorological Data

Year	Monitored Concentration ($\mu g/m^3$) (Denio – Pool)	Modeled[a] Concentration ($\mu g/m^3$)	Modeled/ Monitored Concentration Ratio
2005	167	63	0.38
2006	123	63	0.51
2007	94	52	0.55
2008	34	39	1.15

[a] Average of AERMOD (rural), AERMOD (urban), ISCST3 (rural) and ISCST3 (urban) predicted concentrations

Table 6 – Comparison of Modeled and Monitored NOx (as NO) RRAMP Season Period-Average Nighttime Concentrations at the Church Monitoring Site, Onsite Meteorological Data

Year	Monitored Concentration ($\mu g/m^3$) (Church - Vernon)	Modeled[a] Concentration ($\mu g/m^3$)	Modeled/ Monitored Concentration Ratio
2005	146	37	0.25
2006	116	32	0.28
2007	123	30	0.24
2008	43	23	0.53

[a] Average of AERMOD (rural), AERMOD (urban), ISCST3 (rural) and ISCST3 (urban) predicted concentrations

Figure 37 – Comparison of Modeling Results with Monitor Data, Predicted RRAMP Season Average DPM, Onsite Meteorological Data, Black Carbon (BC) Monitor Data, $PM_{2.5}$ Monitor Data (Denio minus Pool)

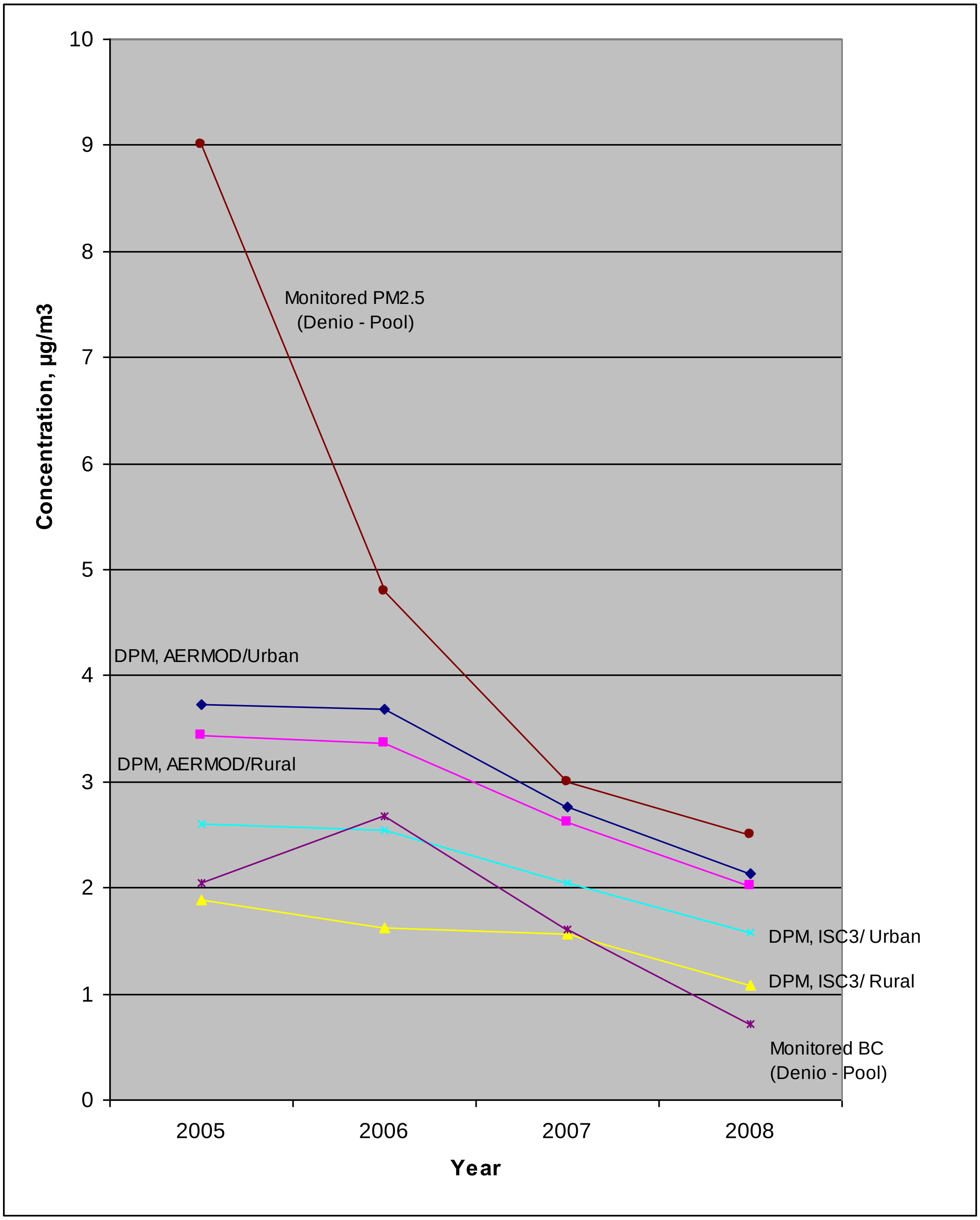
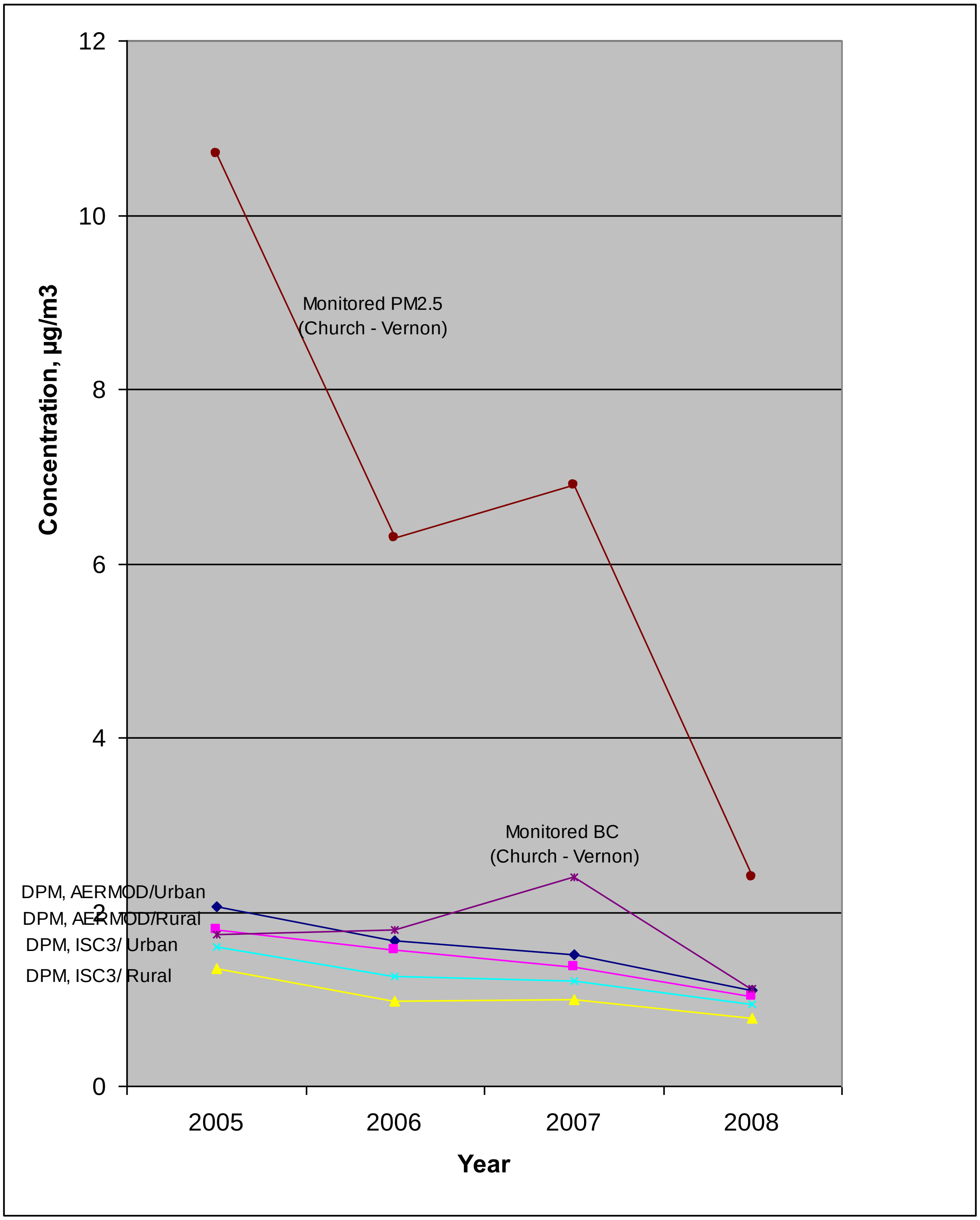


Figure 38 – Comparison of Modeling Results with Monitor Data, Predicted RRAMP Season Average DPM, Onsite Meteorological Data, Black Carbon (BC) Monitor Data, $PM_{2.5}$ Monitor Data (Church minus Vernon)



The most obvious thing about these results is that the measured NOx (as NO) concentrations are much higher than all except one of the model predictions, by a factor of up to 4.[29] This could be caused by multiple factors as follows:

- Limitations in modeling: It is possible that the models systematically underpredicted impacts, at least at the precise locations of the ambient monitoring stations and under the conditions of this analysis. This would seem unlikely, given that the models were developed with the intent that they would be conservative when applied in a regulatory context and have been previously demonstrated to be conservative. In general, air dispersion models work well to predict changes in ambient concentrations at different locations over different periods of time having different emissions. However, models are more accurate at predicting the magnitude of concentrations than at predicting the precise locations where these concentrations might be observed.

- Nearby source or sources, either unaccounted for or inadequately accounted for in the modeling: While the RRAMP study design was intended to eliminate, or minimize, interference from other sources, it is possible that this objective was not consistently met.

- Imprecise characterization of emission sources: The modeled concentrations exhibit a high degree of spatial variability in concentrations in the vicinity of the two downwind monitors. Receptors separated by 50 meters show as much as a 70% difference in predicted concentrations. The highest predicted concentration within 100 meters of the Church monitor site is more than 3.8 times the prediction at the monitor. A small mischaracterization in location or strength of one or more sources could significantly affect the predicted concentration at the monitor site. This is a likely contributor to the observed difference in results.

<u>Comparison of Modeled DPM Concentrations with Monitored Black Carbon and $PM_{2.5}$</u> – There is no ambient measurement method for DPM. DPM is the particulate matter that is emitted from Diesel engines. Because it is a complex mixture of chemical compounds that varies from engine to engine and fuel to fuel, it cannot be isolated chemically from a sample, nor can it be easily distinguished from other particulate matter derived from combustion of fossil fuels. However, it can be distinguished from inorganic particulate matter.

One of the constituents monitored during the RRAMP study was black carbon (BC). BC is formed through incomplete combustion, and consists principally of elemental carbon. Comparison of monitored BC concentrations with monitored $PM_{2.5}$ concentrations provides information about the fraction of ambient $PM_{2.5}$ that is directly emitted by combustion sources (sulfates and nitrates, which make up significant fractions of $PM_{2.5}$, are formed indirectly from pollutants emitted by combustion sources; however, although these particulates can be attributed to combustion emissions, they are not part of DPM).

[29] The maximum factor of 4.9 presented in the Executive Summary is for 2005 and use of all four model/mode combinations, while this factor of 3.8 is for 2007 from Table 6, based solely on use of AERMOD in Urban mode.

Tables 7 and 8 compare modeled DPM concentrations with measured BC and $PM_{2.5}$ concentrations for the Denio and Church sites, respectively, based on the RRAMP season average concentrations for the nighttime hours (10 PM to 5 AM PST) when the wind was blowing from the southeast quadrant; the values are also charted in Figures 37 and 38. The monitoring data presented in the figures are the difference between the downwind and upwind measurements, so as to reflect only the emissions from the rail yard at the monitoring site.

As previously discussed, there is not good agreement between modeled and measured NOx (as NO) impacts. Without resolution of the observed disparity between modeled and measured NOx (as NO), which is a directly measured pollutant, it is difficult to meaningfully compare the modeled concentrations of DPM, a pollutant that cannot be measured directly, with measured concentrations of a surrogate.

Comparisons of the measured $PM_{2.5}$ concentrations with the DPM concentrations predicted by the models also do not show good agreement. However, comparisons of measured $PM_{2.5}$ with DPM predictions are similar to those of measured and predicted NOx. Any adjustments to the models that improve their ability to predict NOx concentrations will likely improve the agreement between $PM_{2.5}$ measurements and DPM predictions.

Comparing data for RRAMP season $PM_{2.5}$ measurements (Figures 37 and 38) with those for NOx (as NO, Figures 39 and 40) shows a qualitatively good match, with significant reductions in concentrations over the RRAMP period and curves of similar shapes at each of the stations. This suggests that the same sources—combustion sources at the rail yard—are responsible for the observed reduction.

BC has frequently been used as a surrogate for DPM concentration. The relationship between BC and DPM varies widely[30] depending on the characteristics of the Diesel engine (e.g., size, technology, maintenance), fuel used, and operating mode (e.g., idle versus high load.)[31] Comparison of the measured BC concentrations with the DPM concentrations predicted by the models showed fair agreement for some years/sites, and poor correlation for others. As discussed above, the models did not accurately predict NOx concentrations. The uncertainty in the model-predicted dispersion of NOx from the facility is also expected to characterize the uncertainty in the model's prediction of dispersion of any other pollutant. Furthermore, NO is a specific chemical compound that is essentially non-reactive under the short transport distances and nighttime conditions evaluated in this study, while DPM was not, and cannot be, directly measured in the atmosphere. The reason for the apparent agreement found in this study between measured BC and modeled DPM concentrations during some years at some locations is not known.

[30] Watson et al, (2008), Table 6-14 where elemental carbon (EC) is assumed representative of BC.
[31] Ireson (2009), p. 31

Table 7 – Comparison of Modeled DPM and Monitored BC and $PM_{2.5}$ RRAMP Season Period-Average Nighttime Concentrations at the Denio Monitoring Site and Onsite Meteorological Data

Year	Monitored BC Concentration (µg/m^3) (Denio – Pool)	Monitored $PM_{2.5}$ Concentration (µg/m^3) (Denio – Pool)	Modeled[a] DPM Concentration (µg/m^3)	Modeled DPM/ Monitored BC Ratio	Modeled DPM/ Monitored $PM_{2.5}$ Concentration Ratio
	Denio - Pool	Denio - Pool	Denio	Denio	Denio
2005	2.1	9.0	2.9	1.42	0.32
2006	2.7	4.8	2.8	1.04	0.58
2007	1.6	3.0	2.25	1.40	0.85
2008	0.7	2.5	1.70	2.36	0.68

[a] Average of AERMOD (rural), AERMOD (urban), ISCST3 (rural) and ISCST3 (urban) predicted concentrations.

Table 8 – Comparison of Modeled DPM and Monitored BC and $PM_{2.5}$RRAMP Season Period-Average Nighttime Concentrations at the Church Monitoring Site and Onsite Meteorological Data

Year	Monitored BC Concentration (µg/m^3) (Church – Vernon)	Monitored $PM_{2.5}$ Concentration (µg/m^3) (Church – Vernon)	Modeled[a] DPM Concentration (µg/m^3)	Modeled DPM/ Monitored BC Concentration Ratio	Modeled DPM/ Monitored $PM_{2.5}$ Concentration Ratio
	Church - Vernon	Church - Vernon	Church	Church	Church
2005	1.7	10.7	1.70	0.98	0.16
2006	1.8	6.3	1.37	0.76	0.225
2007	2.4	6.9	1.27	0.53	0.180
2008	1.1	2.4	0.96	0.86	0.47

[a] Average of AERMOD (rural), AERMOD (urban), ISCST3 (rural) and ISCST3 (urban) predicted concentrations.

Figure 39 – Comparison of Modeling Results with Monitor Data, Predicted RRAMP Season Average NOx (as NO), Onsite Meteorological Data, NOx (as NO) Monitor Data (Denio minus Pool)

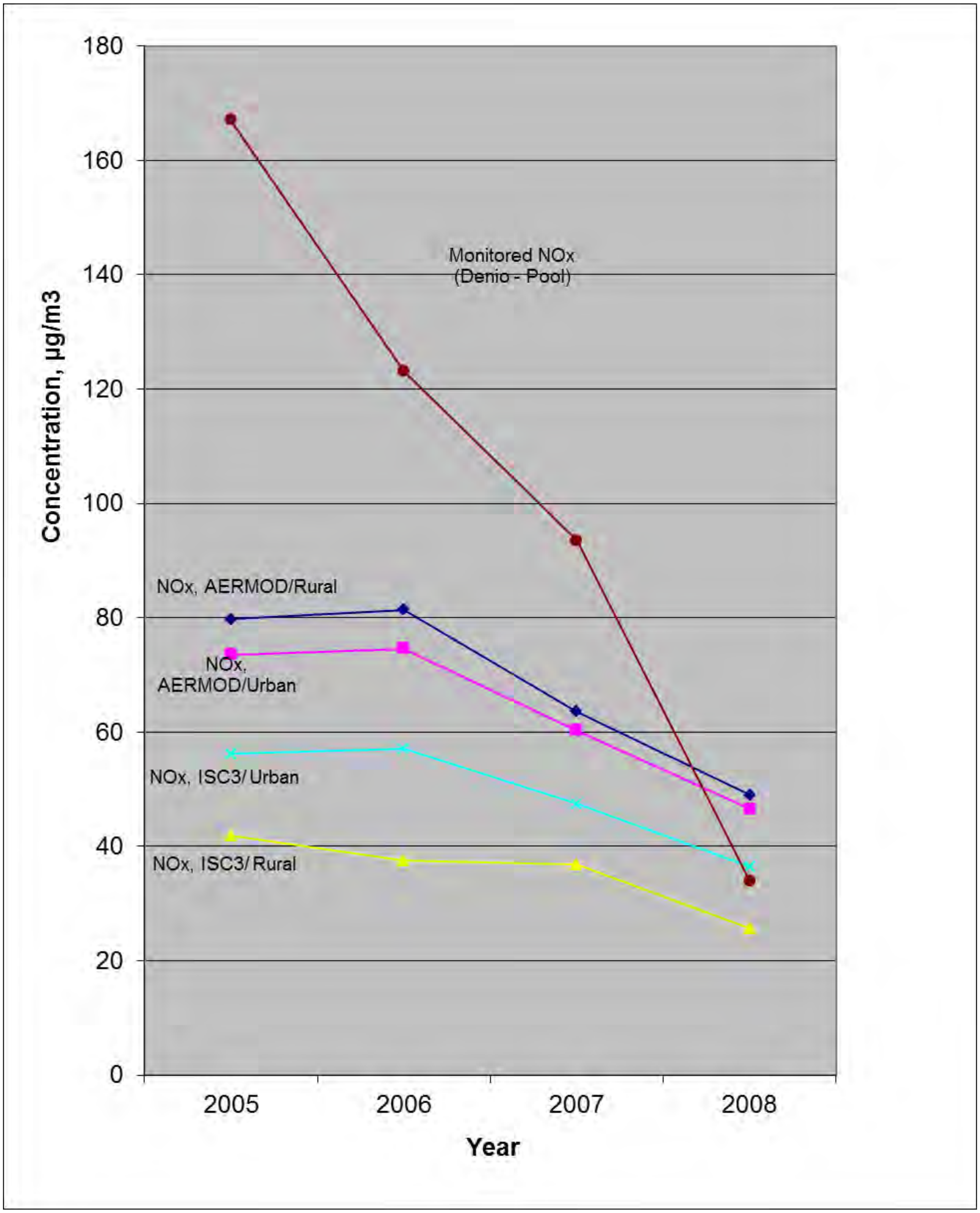
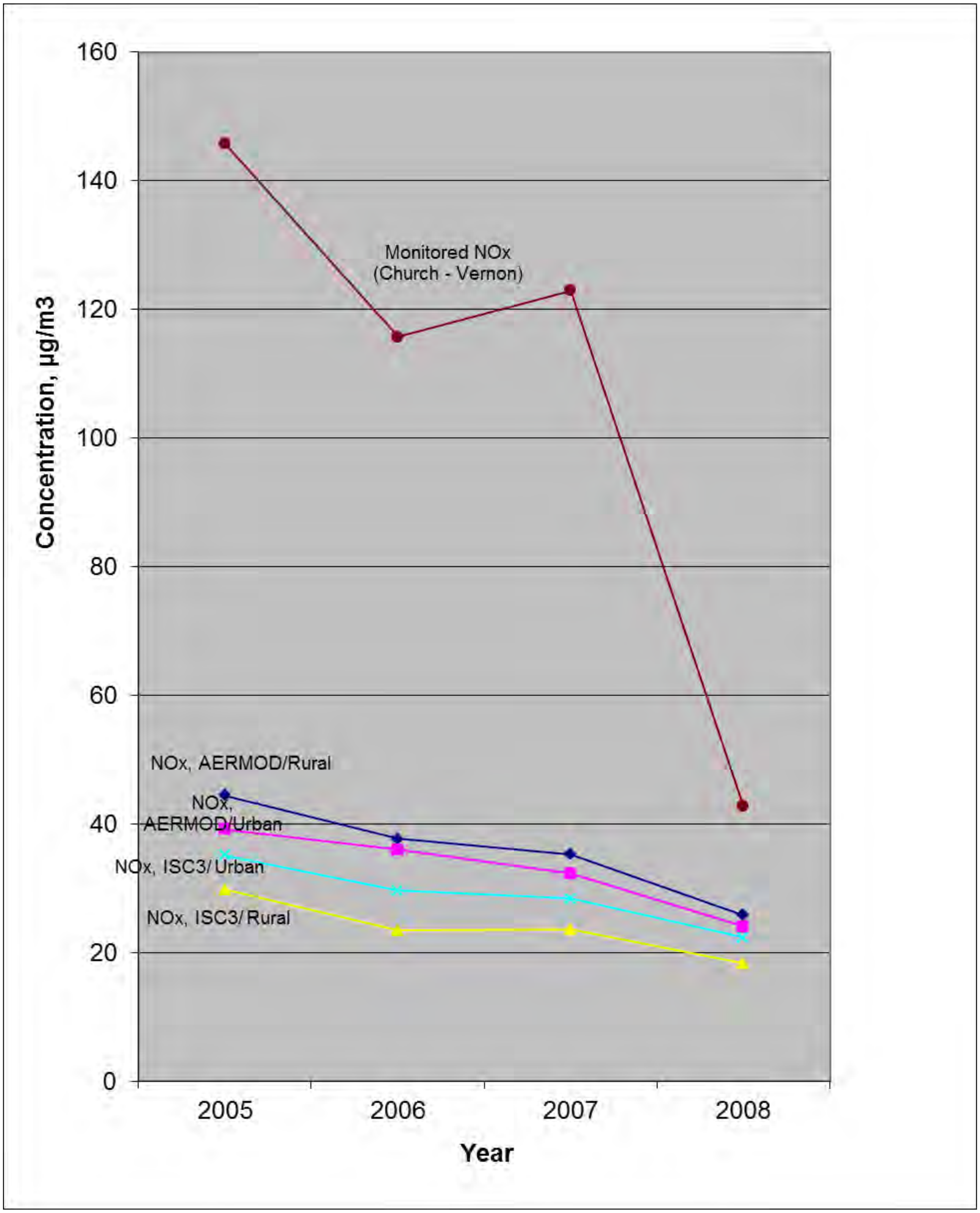


Figure 40 – Comparison of Modeling Results with Monitor Data, Predicted RRAMP Season Average NOx (as NO), Onsite Meteorological Data, NOx (as NO) Monitor Data (Church minus Vernon)



Finally, the RRAMP monitors were located close to the rail yard to reduce interference from other sources. However, they appear to have been located so close to the rail yard that a small change in source location or strength could significantly change the measured concentrations. This trade-off—the need to reduce interference from other sources, as compared with modeling and monitoring uncertainty introduced due to short source-receptor transport distances—is a major factor that needs to be evaluated in any future similar studies.

5.4 Comparison of Results with Other Studies

In other studies, AERMOD and other regulatory air dispersion models are tested for their ability to predict concentrations relative to concentrations of a specified pollutant measured in field studies, and relative to the predictions of the other models. One key study (USEPA, 2003a) compared the concentrations predicted by the then-most-current version of AERMOD (02222) against the predictions of its predecessor EPA-approved model, ISCST3, and two other models, ISC_PRIME and CTDMPLUS. Another key study (USEPA, 2003b) evaluated the ability of the same AERMOD version to predict sulfur dioxide concentrations from several coal-fired power plants, and the concentrations of a tracer, sulfur hexafluoride, released at heights of 29 and 46 meters at a nuclear power plant and at various heights from other stationary point industrial sources.

Differences between these model-testing studies and the study reported herein include the following:

- The older studies typically used large stationary point sources releasing their relatively constant emissions tens to hundreds of meters above ground while this study was based on numerous, relatively small mobile sources releasing their rapidly-varying emissions only a few meters above ground;

- This study used monitors placed close to the emission source area (the rail yard) while the older studies used monitors placed hundreds of meters to kilometers away from the elevated stacks; and

- This study focused on results during seven nighttime hours compared to the use of all 24 hours of monitoring, and on a portion of the year (mid-June through mid-October) compared to the entire year.

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